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JOURNAL OF ECONOMIC ENTOMOLOGY
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The Growing Responsibility of Entomology To Human Welfare

Presidential Address, First Annual Meeting, Entomological Society of America, by Consolidation of American Association of Economic Entomologists 1889–1952, and the Entomological Society of America 1906–1952. December 7, 1953, Los Angeles, California

CHARLES E. PALM, *Cornell University, Ithaca, New York*

Members of the Entomological Society of America and Guests:

This historic meeting, the first annual meeting of the new Entomological Society of America, is a happy occasion. The wishes of the majority of our fellow workers have brought together through consolidation, our two great organizations of the past, the American Association of Economic Entomologists (1889-1952) and the Entomological Society of America (1906–1952), into a single new Society whose interests and work will cover all phases of entomology. I think it is fitting that such union take place as we enter the second century of professional entomology in this country. In the years that have passed, entomology, under the leadership of the men who founded and promoted our two beloved professional societies, has made its fair share of contributions to our national welfare. As we enter the second half of the twentieth century, with its present great struggle between two strong ideologies for the allegiance of the hearts and minds of men everywhere, we in entomology can share the satisfaction that our greatest contributions to man's well-being lie in the years ahead. The full realization of this great service rests in a large measure with the members of the Entomological Society of America. I earnestly hope that our dedication to duty will make the profession and our Society truly great partners cooperating with other sciences in serving the welfare of mankind everywhere.

During this past year, I have enjoyed meeting with you at the five Branches of the ESA, and discussing some of my ideas about the significance of the new Society. The most heartening of all tributes to the new organization are the requests of more than 3,000 men and women for active membership. These entomologists live not only in the United States and Canada, but in many countries of the world. As president, I feel honored to speak on this memorable occasion.

Change is the one sure thing in this living world. Its rapidity sometimes is frightening, yet we witness the increasing tempo of events that surround us with a realization that we cannot withdraw—we are a part of them. Perhaps our greatest hope for offering guidance in this changing world is through a better understanding of the fundamental principles that direct the activities of living things. Events of the past few years in the use of modern synthetic organic insecticides in the field have demonstrated that the balance in nature is by no means fixed or static, but rather is a dynamic, moving balance brought about through the constant inter-actions of physical and biological factors in the environment. This constantly changing balance in nature challenges man's ability to cope with it.

The problems associated with population dynamics in the insect world have attracted the interest of most workers in the profession. Insects are particularly well adapted to rapid reproduction. Their small size, their omnivorous food habits, their versatile manner of producing offspring, their tremendous reproductive potential, ever combine to utilize favorable environmental conditions to produce added populations that clamor for food. If insects seek food or fiber that is of interest and value to man, they become pests. If they transmit pathogens that produce disease in man, animals, and plants, they also interfere with man's well-being. Much has been said about the continuous conflict between man and insects, yet the importance of the conflict increases daily as the upswing in human populations in all areas of the world demand food and fibers as well as protection from insect-borne diseases. The changing demands of the organic world seem inextricably interwoven with the strugggle for food. A century ago, state and federal authorities in the United States recognized the necessity for public support of ways and means for combating injurious insects. Within the experience of the past hundred years, many things have been learned which form the foundations of our present-day effort to combat insect losses, yet in reality as one of our patriots said during the heat of battle, "we have only begun to fight." May we look briefly at some of the different aspects of entomology that today are receiving the efforts of its workers?

For several centuries, the natural history and descriptive phases of entomology have attracted the interests of many capable men. The present estimates of more than 800,000 species of insects that have been described attest to the continuous effort of the taxonomists in collecting and studying our insect fauna. The job is only started. Vast areas of the earth's surface have not been surveyed; new species even turn up in our own backyards! The support for collecting, identifying and publishing the results of these investigations is indeed inadequate. I have no ready solution for the problem, but it is one that must be met through the continuous efforts of all who are interested in the welfare of entomology. A knowledge of our insect fauna in all areas of the world not only furnishes the student of classification with a clearer understanding of phylogenetic relationships, it provides the basis for seeing evolution at work. Identification of a species is essential to workers in applied and regulatory fields since with proper identification comes the key to the accumulated knowledge that may be filed in the literature of entomology. It is gratifying to see some support coming from foundations and government programs that will aid taxonomic investigations. Offsetting this, is the major concern over lack of facilities for publication of important works. The cost of publication has risen so greatly in recent years that most agencies are unable to provide funds for large works in keeping with the availability of manuscripts. This concern should reach every entomologist because taxonomic research is important to him. It should be noted and appreciated that through world congresses and commissions an international approach to the problems of zoological nomenclature has provided the way toward unification of rules and procedures in taxonomic work.

Along with the essential field of taxonomy is the need for support of the related work in comparative morphology, embryology and histology. The functional approach to morphology, and the histochemical studies of tissues will provide a basis for understanding the function of cells, tissues and organisms.

Renewed effort to develop the important field of insect ecology has received stimulus from the use of new insecticides which have disturbed balances and interfered with natural control of some species. Most certainly the addition of these powerful chemicals to the environment constitutes a factor of importance that cannot be fully assayed in a short time. The importance they may play in destruction of some part of the food chain, and in breaking into the pyramid of numbers of organisms contained in the food chain, is also of broad concern to entomologists as well as to field zoologists and conservationists. I refer again to the tremendous reproductive potential possessed by most species of insects, and once the checks and balances are removed, even temporarily, this potential becomes a functional reality. It should be noted that ecology plays an important role in international problems, as for example the explanation of

the behavior and swarming of the different species of migratory locusts. The complicated environmental and physiological effects that seemingly regulate the activities of some of these polymorphic species were capably outlined by Uvarov and Faure some years ago and have implemented progress in the study of locust problems since the key to their origin was discovered. International cooperation to prevent the ravages of locust invasions is another step toward elimination of man-made barriers in our dealings with insects. The development of several apecies of mites, aphids and other insects as pest problems, as the result of the use of insecticides to control other species, is already cause for concern. Much has been taken for granted regarding the importance of natural control of insects; by disturbing it we see what nature is doing and appreciate the tremendous task of population control that can be ascribed to natural factors.

Recently Patton[1] pointed out that an explanation of abnormal function in insects is handicapped by a lack of knowledge of normal function. It was not too many years ago that the departments of entomology at Iowa State College and the University of California were the principal ones in this country that provided instruction and research opportunities in the field of insect physiology. Yet public realization of the importance of this field came only when several of the new synthetic organic insecticides failed to control insects of importance to agriculture and public health where formerly their control was spectacular. Although funds are available from the defense effort and other sources for application to this baffling problem, we lack sufficient trained workers to attack the field in force, and we lack institutions equipped to handle such staffs were they available. Fundamental research is costly, time consuming, and affords little opportunity for accurate forecast of when meaningful results can be expected. Yet our future welfare is firmly woven into its pattern. Our ability to develop and use insecticides effectively is dependent on progress in, and understanding of the physiology and biochemistry of insects. I think that the field of insect physiology illustrates, too, the intricate and essential ties that entomologists have developed with other fields of science. The broad field of chemistry and in particular biochemistry as well as biophysics and mathematics are areas of support for research in physiology. Physiological research is a slightly different problem for the average entomologist, because he is dealing here with activities he cannot see and describe in terms that to him are conventional. It is the teamwork approach to basic research that characterizes the research of entomologists in many fields today, and most certainly it will expand in that direction in the future. It is for this reason that the graduate student and his advisors are hard pressed to include during the short years of graduate study, the training that will be essential for a lifetime of productive work. With this cooperative approach, the entomologist is expected to uphold his end of the contract in entomology, yet be familiar enough with his collaborators and their work to integrate and forward the program. Although there is much discussion for the support of insect physiology, many administrative groups in our colleges and experiment stations still find it easier to get funds for preventing the losses caused by insects, rather than to establish and maintain an objective long-range program of research. The seriousness of insect resistance to insecticides, however, is closing the ring and may provide the opportunity for support of basic physiology, biochemistry, and genetics of pest species. The fascinating studies of the physiologists on the effect of hormones and enzymes on metamorphosis, metabolism, growth and reproduction in insects are as intriguing as they are important.

No discussion of essential research in entomology is complete without a look at the beneficial insects. Fortunately there are many. As previously indicated, we find out every year through upsetting natural balance, that natural control is taking place without our knowledge or consent. We have made spectacular strides in many areas of the world through the use of biological control measures. No group, perhaps, deserves greater praise for its contributions than the men here in California. Research is broadening our knowledge of biological control agents to include the use of bacteria, fungi, and viruses, as well as insects and even verte-

[1] Patton, R. L. Invitation Address, Plant Protection Society of Quebec, April 21, 1953.

brates. Plant pests as well as noxious insects themselves are being controlled by insects. Research with bees has shown their value to man is great in terms of honey and wax produced, but even greater in the benefit derived from them through pollination of crops for seed and fruit production. Studies on wild bees and other pollinating agents are revealing many natural benefits of which we were unaware. It becomes more evident, I think, that there are indeed few fields in which insects do not touch upon the welfare of man, either for gain or loss.

As members of the Entomological Society of America, we must exert influence in stimulating and directing research in the various areas of fundamental entomology. The benefits will be enormous, yet the responsibility for obtaining support and directing the effort is definitely ours. Our greater responsibility to human welfare demands our vigorous support of and cooperation with related fields of science in forging ahead with expanded programs of fundamental research. We will continue our support for programs involving the safe use of insecticides and up-to-date legislation dealing with pesticide registration and residue tolerances. It is to be remembered that from studies of insects, much has been contributed to research in other fields. The fruit fly has become almost synonymous with genetics and as a geneticist recently said, "look what genetics did for the fruit fly!" Animal nutrition, distribution, evolution of social instincts, the nature of the species, population dynamics, are but a few fields of broad biological interest that have profited from the use of insects as experimental animals.

The concern over growing human populations has brought forth speculation of thinking men for centuries. Yet as the growth continues, as the life span of individuals in many countries increases, the problems associated with food and fiber production as well as the protection of public health have become increasingly acute. Our argicultural economists estimate that our own population is increasing by 2 millions a year. By 1975 the population of the United States conceivably may be around 190 million people. Expressed another way, for every four people who sat down for a meal in 1950, five will sit down in 1975. The important question is how will that fifth plate be filled? DeGraff[2] pointed out that there was a 43 per cent increase in our population between 1920 and 1950, yet the 151 million people of 1950 ate from essentially the same cropland acreage as the 106 million people of 1920, and ate better. This is the commentary of what science already is offering the American people in terms of food production. It is obvious that many factors and efforts contributed to this remarkable achievement, yet insect control can be singled out for its fair share of credit at almost any step along the way. The uphill struggle to produce more, at less cost, and with less loss to insect pests, is a mightly challenge for the future, yet I have every confidence that entomologists will do their job in contributing to the over-all well-being of our nation. The struggle is continuous—we will never get rid of insect pests; most likely we will accumulate more!

Insect vectors of disease pathogens which cause losses of health, productivity, and life itself in plants, animals, and man are a constant menace to human welfare. In the field of human health alone, Knipling[3] estimated that 5,000,000 lives have been saved and 100,000,000 illnesses prevented since 1942 by the use of DDT for the control of insects associated with malaria, typhus, dysentery, and other insect-borne diseases. This indeed is a bright achievement of entomology in public health and illustrates the potential responsibility the profession must fill in the complex pattern of growing human populations. The incidence of malaria in the United States is at an all-time low because of effective work of entomologists and public health officials. I have seen the stark realism of survival in some of the under-privileged areas of the world. It is little wonder that people without anything to lose, except life itself, will follow those who promise a better lot. I am convinced that the control of insects that destroy crops and transmit diseases can contribute materially to increasing food, fiber, and health of these peoples and in turn be of value toward reducing world tension. It has been suggested that increased food production in many of these

[2] De Graff, Herrell. What does science promise for the American diet? Address presented at the 14th Annual National Farm Institute, Des Moines, Iowa. February 15, 1952.

[3] Knipling, Edward F. The greater hazard—insects or insecticides. JOUR. ECON. ENT. 46(1): 1–7. 1953.

areas will result in increased population, and no over-all gain in living standards. However, may we remember that progressive nations long ago found it wise to free a part of the population from the necessity of food production in order to make advancement in the arts and sciences. We shall watch with much interest the international programs of pest control which our government, the United Nations, and various nations and world philanthropies are conducting to raise the lot of those less fortunate than ourselves. Insect control enters the plans of almost every agricultural and health program of international scope.

The United States Department of Agriculture estimates that we suffer losses from insects in our country amounting to $4,000,000,000 annually and $3,000,000,000 from plant diseases. I feel that the Department is to be congratulated for its excellent presentation to the public of the work and effort of the fields of entomology and plant pathology through the 1952 and 1953 Yearbooks of Agriculture. It is important to ask ourselves what the loss figures would be were not the best efforts of these two professions engaged in all-out programs of pest control? Would we be the best-fed nation with the highest living standard? A serious appraisal of this aspect of the question will be made by two of our guest speakers later on this program. In the production programs of the American farmer, requirements for maximum yields and minimum losses are economically essential. Consumer emphasis on quality produce imposes additional reason for pest control. The use of pesticides has increased enormously in recent years, because of their value in minimizing losses from pests. The U.S.D.A. Bureau of Agricultural Economics estimates that American farmers are spending around $300,000,000 annually for pest control, an amount equivalent to one per cent of the value of farm crops. The agricultural chemical industries of the nation spend an estimated $8,000,000 annually on pesticide research to provide new and more effective chemicals for agriculture and public health. In addition, members of the National Agricultural Chemicals Association are supporting research in colleges and experiment stations. Recent figures indicate that eight member companies in 1952 provided a total of 48 fellowships at a cost of $102,500. Cooperative research grants, including money and chemicals from 16 companies, involved $87,750. The entomologists appreciate the help and cooperation of the chemical industries. We also appreciate the agricultural press which has aided in distributing up-to-date information to farmers and others concerned with insect control.

Mention has been made of international cooperation in various phases of our science. The "one world" approach to all aspects of entomology is rapidly becoming a reality and in fact is the only sane method to follow. During the past 15 months, I have been privileged to travel some 30,000 miles to England and France, Central America and all parts of the United States in attending entomological meetings. Fortunately, there are no territorial boundaries to the exchange of entomological information throughout the free world. The exchange of students and professional workers increases the opportunity for clear understanding of problems and interests. International congresses and meetings as well as international business in pesticides and application equipment serve to secure the benefits for many areas that our knowledge and materials can provide. The revolution that European scientists began in the field of insecticide chemistry has touched off an entirely new day for applied entomology. It has also created new challenges for those working in fundamental fields. Is it any wonder that an entomologist's lifework is never dull!

Any organization with more than 3,000 active members must be handled on a business basis. I am happy to say that the Interim Board has selected Dr. Ashley B. Gurney as the Exceutive Secretary of the Society; with a full-time executive, many of the benefits of the merger can be realized. During this transition period in 1953, committees studying numerous problems that have a bearing on the efficient operation of our organization, have provided reports for formulation of Society policies. I have invited the members of the incoming Governing Board, as well as the Chairmen of the Branches, to meet with the Interim Board to provide the best judgment available in establishing our policies and to avoid any loss of time in becoming familiar with Society busi-

ness. May I acknowledge again my deep appreciation to everyone who has helped this year. With the strong feeling among the membership for the welfare of our profession and its national Society, there can be no doubt as to the future greatness of the Entomological Society of America.

In general terms, I have tried to indicate that entomology has developed from its natural history and descriptive beginnings through the comparative phases of its work and that, with support of private and public funds, all of the phases of fundamental and applied entomology have expanded into national prominence. Its staunch support by farmers of the nation through the era of great expansion from the days following the Civil War, to the present, is praiseworthy. The growing complexity of the profession requires integration and cooperation with many other fields of science and industry. The need for maintaining a strong leadership in entomological research, control, and regulatory work in our national government must ever be brought before the administrators reponsible for the profession's welfare in the Department of Agriculture. The key to future gains, and our ability to serve, lies in the support and conduct of basic research in broadest terms for all aspects of entomology. The entomologist can no longer withdraw from his obligation to share his knowledge about insects with the public which must be informed if it is to support him adequately. Entomology's stimulus, its challenge, is that tomorrow always offers a greater opportunity to serve than today. It is constantly assuming greater importance as civilization progresses and as populations increase Man and insects will always engage in competition. Yet the thrill of seeing a butterfly emerge from its chrysalis, a dingy dragonfly nymph crawl from its muddy shoal to transform into a gorgeous creature that will share another world—these, too, are the experiences that cannot be forgotten by the men and women who love the world of insects. There are many facets to the picture we call entomology. Truly, those who enjoy it, who work and revel in its interests find it not only a profession, but a grand way of life. Long may they live and serve their fellow man!

Insect Eradication Procedures in Incipient Infestations[1]

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The attempted eradication of an insect species is not to be entered into lightly, regardless of how incipient the infestation may appear to be. Their high reproductive capacity and ability to disperse widely and rapidly, and particularly the difficulty of determining accurately all existing infestations, seriously depreciate the possibility of success. However, where the economics of the situation merits such consideration, one should not be discouraged from making the attempt. Even if ultimately unsuccessful, it may delay outward spread until effective control measures can be developed, if not previously known. It is even possible that the greater part of its pest importance, if it became necessary to accept it as an established species, might be nullified by such action and the expense incurred, fully justified.

While any such attempted eradication has within itself certain elements peculiar to the species of insect involved, a relatively uniform approach is permitted which, with minor variations, can be applied in all cases. Basically such action should include the application of effective chemicals or processes to all host plants within a selected radius of a known infestation, such measures to be conducted for 3 consecutive years followed by 3 years of intensive survey, the entire program to be initiated or reinitiated with the last finding of a living specimen of the species under attack.

However, in embarking on any insect eradication program there are certain principles and procedures which should be given most careful consideration. Each is essential to the attainment of the objec-

[1] Presented at the Annual Meeting of the American Association of Economic Entomologists, Philadelphia, Pennsylvania, December 16, 1952.

tive. They are here presented in the order of their importance with reference made showing their application to typical eradication programs such as are currently being conducted in California.

INFESTATION SHOULD BE INCIPIENT—The possibility of success is very closely tied in with the extent to which distribution occurs at the time of initial finding. It is important that infestation be relatively restricted and that a reasonably workable program be put into effect immediately which may subsequently be modified in conformity with findings. Otherwise, if action is delayed until extended survey can be made to determine whether the species occurs over a wider area, or until the measures used can be fully supported, the infestation, due to interim natural spread, ceases to be incipient. As a result the measures required become either economically or physically impractical and the opportunity is lost.

When the western grape leaf skeletonizer was first found in California its previous history was adverse to any consideration of eradication. However, in the succeeding 5 years conditions developed which made such an attempt seem advisable and still practical. Unfortunately, during that 5 years outward spread occurred which it subsequently proved was impossible to overtake and after 8 years' effort the program necessarily reverted to a holding or delaying program. There is, of course, no assurance that it could have been accomplished if initiated when first found, but obviously the delay was in no way helpful.

POSSIBILITY OF IMMEDIATE OR EARLY RE-INTRODUCTION—It would obviously be unwise, economically, to attempt the eradication of a species where there was every possibility of its immediate or even early re-introduction, particularly through natural spread.

As an example, California has recently waived any attempt to eradicate an incipient infestation of pear psylla found this year along the Oregon border for the first time in the State. This decision was made, regardless of the recognized importance of this species as a pest of its host, because the infestation results from natural spread from the north to which the State will be continuously exposed. Further uncontrolled spread within the State could be expected from these original infestations regardless of any action that might be taken. A similar situation was responsible for the failure of a well organized and well executed attempt on the part of the Federal Bureau of Entomology and Plant Quarantine to eradicate the earlier initial infestation west of the Continental Divide at Spokane, Washington.

LIMITED HOST RANGE—Generally speaking, eradication effort should be restricted to insects having a very limited range of hosts. Of those conducted in California three have each been concerned with a single host. The others have a very limited host list. Eradication of the olive scale, *Parlatoria oleae* (Colvée), which appeared in California at the same time as Hall scale, *Nilotalspis halli* (Green), and indicated equal economic importance as a potential pest of deciduous fruits, was never considered because it has over 200 species of host plants. Citrus white fly, *Dialeurodes citri* (Ashm.), in addition to citrus has 14 primary and 16 secondary plant generae and species among its hosts most of which are widely grown in California either commercially or as ornamentals. However, it was early learned that the secondary hosts can be completely ignored as they enter into the problem only in the presence of heavy populations on adjacent primaries thus materially reducing the number coming under treatment in any eradication effort.

ABILITY TO DETECT EXISTING INFESTATION—One of the greatest obstacles to the eradication of an insect lies in the difficulty of detecting all existing infestation as a basis for treatment. Visual inspection is entirely inadequate for that purpose. As a rule an infestation has to reach a certain population density before its presence can be detected in that manner. In the interim outward spread is permitted which can not be detected until it in turn reaches a similar density. This situation could be continued indefinitely, if depending on inspection, not only until the host limits were reached but with the possibility of the species eventually being re-introduced into the original location.

Traps, baited with a lure attractive to adults of either or both sexes, can be quite helpful in meeting this problem. However, the availability of such lures is quite limited. Only one has been practical in connection with the projects conducted in

California. Ammonium carbonate in combination with a sticky-sided container, as developed by Dr. Kenneth Frick of Orgeon State College, has aided in the survey for cherry fruit fly, *Rhagoletis cingulata* (Loew.) though its effective range is quite limited and all too frequent replacement of the lure is required. Its use has been supplemented by what is known as the Howard[2] method used in the examination of random fruit samples by mechanically crushing them and separating out any larvae from the pulp by a water flotation process. A 12 per cent infestation has been detected by the latter process where traps failed to capture a single adult.

TREATMENT MORE DEPENDABLE AND LESS EXPENSIVE THAN INSPECTION—In most instances treatment is much simpler to apply and less expensive than any type of inspection, and far more dependable. For that reason it has been found most practical to apply the planned treatment measures to all hosts within a suspected area of infestation rather than restricting them to known infested properties or hosts as determined by visual inspection or trapping.

In defining such an area it is usually drawn as a safeguard measure so as to include all hosts within twice the radius of the anticipated distance of seasonal or detectable natural spread from a known infestation. Uuually the area, as finally drawn is very irregular in outline, following property lines extended to include any property or cultural unit any part of which falls within the radius being used. This action is based on the possibility of spread being furthered by practices within a cultural unit.

A typical example of the value of this approach is found in the current federal-state-cooperative effort to eradicate Hall scale, of which the only known infestation in the Western Hemisphere lies in California. In the earlier stages of the project, dependence was placed on visual inspection in determining the infested hosts to be treated. Each year, however, new infestations were being found which were obviously the result of spread but not previously detectable. As a result the program was necessarily being extended year after year with the time of completion highly indefinite. During that period a pattern of occurrence was noted suggesting 1,250 feet as representing outward spread that might be expected to occur before its presence could be detected. The treatment program was therefore modified to include all hosts within twice that radius, or within 2,500 feet, of a known infestation. This action was later justified when new infestations were found outside of but well within that distance of infestations previously presumed to have been eradicated. Had the radius later adopted been used in the earlier work, these later infestations would have been eliminated without ever having been found or given the opportunity for being responsible for further spread.

TREATMENT AREA BASED ON RATE AND DIRECTION OF NATURAL SPREAD—The method used in defining an eradication treatment area is based on the probable radius of natural or detectable spread from a known infestation, within a given season or period. Often this has to be an arbitrary conclusion based on assumptions and later modified as more accurate information is developed. If eradicative action were to be delayed until this point could be determined the infestation would cease to be incipient and the eradication problem increased many fold if not to the point where the effort would no longer be practical. Usually there is knowledge on which immediate action can temporarily be predicated.

Even with active fliers, natural spread has been found to be materially restricted by the abundance of acceptable hosts within the immediate vicinity of established infestations. Under these conditions it was found to be not more than 300 feet with respect to citrus white fly with a 600 foot radius used in determining the area of treatment. Spread of Mexican bean beetle, *Epilachan varivestis* Muls., in large areas of contiguous plantings seems restricted to a radius of one-half mile indicating need of a 1-mile radius in defining the treatment area. Adult cherry fruit flies seem disinclined even to cross the road to another orchard, excepting in the absence of host fruit, though wind, on occasion, seems to have been responsible for spread up to 2,500 feet. On the latter basis one-half mile has been used in

[2] Developed by B. J. Howard, Michigan State Department of Agriculture.

defining a treatment area. With static species, such as Hall scale, past history indicates 1,250 feet as representing the first detectable spread and, as previously discussed, 2,500 feet used as a radius. The western grape leaf skeletonizer has presented a somewhat different picture, recording seasonal spread of approximately 12 miles in the direction of the prevailing wind immediately following a light rain. As a result, 25 miles was the width used in establishing a host free barrier around the periphery of the infested area to prevent or discourage outward spread while applying treatment to all hosts remaining within the area surrounded.

Natural spread of all insect species is expected to occur to all points of the compass from an established infestation through it is usually greatest in the general direction of the prevailing wind. Allowance must be made accordingly when defining eradication treatment areas.

GENERAL TREATMENT PROCEDURES—Having defined a treatment area it is obviously important that there be available chemicals that can be applied as sprays or dusts or incorporated in the soil in reducing the major part of the insect populations involved. The chemical selected should be applied to all host plants within the area throughout their growing period. The initial application should be adjusted to the life history of the insect in relation to its earliest seasonal attack on its host. The subsequent interval of application should be adjusted to the rate of growth of the host plant and the residual life of the chemical used in order to assure as complete coverage as possible throughout the season. Where the hosts treated are to be harvested and used, chemicals should be selected that can safely be applied under such conditions.

In the case of Mexican bean beetle, 1 per cent rotenone dust was used starting with the four leaf stage of the plant and continued every 2 weeks until the crop was harvested or the foliage dried up. With respect to Hall scale, infestations have been given an oil spray which immediately reduced further build up and possible spread pending fumigation during the winter or dormant stage with high concentrations of cyanide under gas tight tents. Weekly applications using 3 pounds of 50 per cent wettable methoxychlor in 100 gallons of water, have been used against the cherry fruit fly, being initiated 2 weeks in advance of the average spring emergence date of the fly from overwintering puparia as recorded in areas where this species is established and continued 2 weeks after the normal maturity and harvest date of all varieties. Citrus white fly has responed to a single cover spray of 1.66 gallons of a light-medium emulsive oil in 100 gallons of water applied in late fall or relay spring when all individuals are in the larval stage. Sodium fluoaluminate applied as a dust at the rate of 30–50 pounds to the acre has served against the western grape leaf skeletonizer, treatments being initiated approximately 30 days after the emergence of adults from overwintering caged pupae, usually around June 1st, and repeated in mid-July to catch the second generation larvae.

New infestations associated with any eradication project or against which eradication measures are contemplated should always be treated immediately regardlesss of the stage of the insect involved, using the most effective material available. This action is important in reducing their numbers and in discouraging increase and further spread pending later treatment under more optimum conditions.

LEGAL ASPECTS OF ERADICATION PROGRAMS—It is important, if not mandatory, that legal authority be available for permitting the treatment procedures involved which may need to be extended to exposed as well as known infested hosts or properties. In California, that authority is contained in the State Agricultural Code, or is established by public hearing at which all interested parties may be heard for which provision is also made in the Code.

The law, however, is weak, both locally and nationally, in the matter of making provision for host removal which action, if permitted, can very materially decrease the cost of operations. In one instance, $75,000 has been expended in treating orchard trees that could have been purchased for $8,000, and destroyed when first found infested. Each cherry tree removed represents a minimum saving of $100 in treatment costs in that project.

Also, obviously, the fewer the number

of host plants involved the greater the possibility of attaining the objective. A certain amount of such host removal can be accomplished through voluntary cooperation of the owners. In other instances, it could be arranged on a reasonable reimbursable basis, if legally permitted.

Until very recently Congressional policy had not permitted funds appropriated for insect pest eradication to be used for any purpose that might improve the property and had ruled that removal of an infested tree or plant constituted such improvement. State legislative policy will permit the expenditure of such funds for host removal, but as with the Congress, will not permit their use in any way that might be interpreted, except in special instances, as reimbursing the owner for his loss. Specific legislation is required approving such action with respect to any extension of this authority. The time element involved in securing such legislation precludes funds being made available during the important, earlier stages of a program.

The elimination of all hosts, however, in following what is commonly called a "scorched earth policy" is believed to be applicable only to static species such as a scale insect. It is not to be considered where a free flying insect is concerned except in creating a host free barrier to outward spread. Otherwise, it is an invitation to immediate dispersal. The importance attached to the necessary presence of hosts in an eradication area is included in the measures directed against the Mexican bean beetle. In this project, each spring, 30 days in advance of commercial plantings, trap beans have been planted around the margins of fields that had been infested the previous season. The purpose has been to attract and hold any early emerging adults from winter hibernation that otherwise might have dispersed in search of acceptable hosts and thus responsible for long distance spread.

In the case of the cherry fruit fly it has been found advisable to permit some fruit to remain to attract any adult flies that might have survived the treatment measures and otherwise disperse. Such fruit, however, is permitted only where it can be controlled and destroyed before it can serve as a means of maturing any larvae.

PUBLIC RELATIONS.—In bringing all hosts within any selected area under treatment, both those exposed to infestation as well as those known to be infested, a major public relations problem is developed. Not only is legal authority required for extending treatment to properties or hosts on which actual infestation has not been found, but it requires the utmost diplomacy to sell that idea to the owner. He must be convinced that such action is essential to the success of the project and his cooperation secured and maintained until the project is completed. As the program progresses and infestation becomes progressively more difficult to find, this same situation extends to all property owners within the area.

In many instances the area of infestation and treatment is completely disassociated from the commercial areas of production of the crop being protected. This has been partiuclarly true with respect to citrus white fly which has so far been restricted in its occurrence to ornamentals on residential properties, though sometimes in close proximity to commercial plantings. The western grape leaf skeletonizer occurs in an area in which its host is of very minor importance, the threat of its presence there being to 50,000 acres of wine and early table grapes 50 to 100 miles to the north and to 500,000 acres in the San Joaquin Valley still further to the north. The cherry fruit fly is found in a non-commercial area of scattered trees which are valued particularly for their historic, esthetic, or shade value. Its presence is of no real concern to the owners but is of concern to a $10,000,000 cherry industry in the central coastal part of the State 200 miles to the south to which it could chainspread on scattered yard or farm trees if allowed to persist. These situations also call for the maximum of tact in securing and maintaining the cooperation of owners over the long period involved who have little or no direct interest in the problem and are personally inconvenienced by its conduct.

MINIMUM TREATMENT PROGRAM.—In carrying out the overall treatment of a defined area experience has demonstrated that from the standpoint of eradication dependence should not be placed in a single season's treatment, no matter how efficient the materials used may be, nor should one be mislead into believing that

eradication has been accomplished by immediate failure to find any survivors. Allowance should be made for both human and mechanical error as well as to compensate for pertinent biological factors in some instances.

Generally speaking, a period of three annual consecutive treatments without the finding of a live individual of the species against which the measures are being directed, is advisable in all eradication projects. With completion of this treatment program the area should be subjected to intensive inspection for another 3 years with continued negative findings before officially declaring eradication as having been accomplished. At any time that a live specimen of any stage of the species under eradication is found, the 6-year program should be re-initiated from that point.

While a 6-year minimum program is indicated, experience in California has shown that a much longer time usually elapses before success can be accurately declared. Initial infestations of citrus white fly in California which were fairly wide spread before effective measures had been fully worked out, required 18 years to complete. Subsequent incipient infestations, in no way associated with the earlier problem, resulting from later separate introductions, have responded to the minimum 6-year program. Hall scale is in its 13th year with at least 4 more years required under the most favorable conditions. Mexican bean beetle seems to have responded to a 10-year program. Cherry fruit fly is in its third year with a minimum of three to go. Western grape leaf skeletonizer, for reasons previously explained, has reverted to a delaying program after 8 years pointed at eradication.

CONTINUING SURVEY.—The success of any eradication project is dependent on continuous periphery survey during the treatment period to assure, as far as it is possible to determine, that all existing infestation is being included. Following completion of the planned treatments such survey should be extended to the treatment area for the 3 years prescribed, to pick up any infestation that might remain due to some failure in operations, as applied. At the same time periphery survey may be abandoned or at least conducted on a less intensive basis as it has been carried out during the previous 3 years of treatment with negative findings and with the source of outward spread during that period assumed to have been removed.

In general, the periphery survey should be conducted on an intensive basis in the area immediately adjacent to the treatment area and less intensively as the distance from the latter until it resolves itself into what might be termed "scouting." Using Mexican bean beetle as an example: All plantings of beans within 1 mile of a known infestation were kept under treatment. In the next half-mile radius 50 to 70 men have been employed throughout each season walking out the plantings in this area every 2 weeks, 6 rows to a man, 3 on either side, as he crosses the field. In the next half-mile radius inspections have been made by the same crews every 30 days on a 12-row basis, 6 on either side, and in the balance of the area representing approximately 60,000 acres laying between two parallel mountain ranges leading down to the ocean, a scouting survey has been carried out twice each year on the basis of 24 rows, 12 rows on either side of each man.

The use of tinted glasses greatly facilitates inspection by taking the sheen or glare off of the foliage and in reducing eye strain. To maintain their interest the inspectors are required to collect and submit for identification any insect they may find being careful to avoid multiple replication. At 2-week intervals the inspectors are shown film in color covering the various life history stages of the beetle and typical host damage. Otherwise, during 3 months of negative findings they could easily lose sight of their objective.

Similar surveys are conducted in conjunction with other projects, being modified to meet their repective needs.

QUARANTINE PHASES—An important phase of any insect eradication project is that of establishing safeguards confining infestation to the occupied area as closely as is possible and maintaining them throughout the life of the project. In this the Bureau of Plant Quarantine cooperates closely with the Bureau of Entomology in California. Concurrent with the establishment of eradication and treatment areas a quarantined area is defined within and from which the movement of

potential carriers is restricted. In general the measures taken prohibit the movement of such carriers from any known infested property except under supervised pretreatment. Movement from other properties within the quarantined area is unrestricted but is subject to treatment as a condition of movement to points outside. The eradication area is purposely made fairly large to permit immediate expansion of the measures being used in conformity with inspection findings. The treated area is restricted to limits drawn as previously discussed in relation to the probability of spread from a known infestation. The quarantined area may fall somewhere in between these two usually closely following natural barriers to spread if present. Following completion of treatment activities the quarantine is usually immediately revoked.

FINANCIAL CONSIDERATIONS—While the expense of eradication projects is a relative matter with respect to the value of the crops being protected, such measures are not to be entered into lightly from the financial standpoint. Experience has indicated that the annual cost ranges from $25,000 to $200,000 when dealing with incipient infestations. The initial expense and early treatment years call for the heaviest expenditures, tapering off appreciably during the final years. The total cost of most of the projects undertaken in California have each exceeded $250,000. The amount expended on Mexican bean beetle to date totals $840,000 with 2 years' inspection yet to be completed. The amount expended in 8 years on the western grape leaf skeletonizer has been $747,000, on the citrus white fly $285,000, and on cherry fruit fly at the close of the third year $75,000. Total state-federal expenditures for Hall scale will have exceeded $1,000,000 by the close of 1953.

Obviously, therefore, there must be assurance at the outset that funds will be available to complete the program. Otherwise there would be no purpose in its being started. These figures are not quoted for the purpose of discouraging anyone who might have reason for attempting the eradication of a potential insect pest, but to point out the financial responsibility assumed in so doing.

SUMMARY.—The major factors involved in any attempted eradication of an incipient infestation of an insect are time, ample funds, legal authority, and the continued cooperation of those inconvenienced by the operations. The biological and physical factors involved become secondary until assurance can be obtained that these conditions can be met.

The biology and ecology of the insect concerned must indicate reasonable feasibility in such an attempt. The variety of hosts should be limited. Their numbers should be reduced by removal and destruction wherever possible. Effective chemicals should be available to meet treatment requirements.

Inspection is inadequate in determining all existing infestations necessary to accomplish eradication. Treatment should therefore be extended to all hosts within a selected area based on the radius of anticipated annual spread from a known infestation including as a safeguard measure, a buffer zone usually equal to that radius.

The minimum operating program should include three annual consecutive treatments followed by 3 years' intensive inspection without finding a living individual of the species concerned before officially declaring such an attempt completed. This may be modified to meet the conditions peculiar to any specific problem, but in general could be closely followed, profitably.

Quarantine safeguards against outward spread should be set up immediately and continued throughout the treatment period.

The term "incipient" as applied to this problem should be interpreted literally as meaning "in the beginning" if the action is to be conducted at minimum expense and with any reasonable expectancy of success.

Field Tests with Tick Repellents—1949, 1950, and 1952[1]

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Field tests with selected tick repellents were conducted in South Carolina and Georgia during the summers of 1949, 1950, and 1952 in various areas heavily infested with nymphs and adults of the lone star tick, *Amblyomma americanum* (L.). The repellents were selected on the basis of their performance in laboratory screening tests. The best repellents in the early tests were later combined with outstanding mosquito, chigger, and flea repellents to provide an all-purpose mixture. The results of the laboratory and field studies that preceded this work have been reported by Smith *et al.* (1948, 1950) and Cole *et al.* (1950, 1951).

Toxicological investigations of many of the compounds are incomplete, and these results are presented as an indication of the present status of research, not as a recommendation for general civilian use. Several of the compounds are considered safe for use on mature men under supervision, such as troops. Others have been shown to be unacceptable toxicologically since these tests were conducted.

METHODS AND MATERIALS.—All the materials were tested as clothing treatments on regulation two-piece army fatigue uniforms of cotton twill. The individual compounds were applied at the rate of 2 grams per square foot of cloth, and the mixtures at rates ranging from 1.5 to 3.6 grams. The uniforms were usually impregnated with emulsions or solutions of the repellents, but a few treatments were made with sprays and aerosols. From 1,500 to 1,650 ml. of solution or emulsion was used to impregnate a single uniform, consisting of fatigue jacket, trousers, and socks. To emulsify the repellents, 10 per cent of Tween 80 (polyoxyethylene sorbitan monooleate) was dissolved in the liquid compounds, and the solid compounds were dissolved in an equal weight of xylene to which 10 per cent of Tween 80 was added. Treated uniforms were aged on hangers in a ventilated room and tested about once a week for 3 to 6 weeks. Ineffective uniforms were usually discarded after 2 weeks.

Subjects wearing the treated uniforms were exposed in tick-infested territory for 1 or 2 hours, depending on the abundance and activity of the ticks. During this time the subjects alternately walked about, sat, and lay on the ground, all doing the same thing to give equal exposure. After the exposure they stayed in an uninfested location for a half hour, to give the ticks time to attach or to drop off or die, according to the effectiveness of the chemical. In each test one subject wore an untreated uniform as a check.

At the end of the waiting period the uniforms were removed and all ticks on the clothing and body were counted. Attached and unattached ticks were recorded separately. The effectiveness of the chemical was determined on the basis of the number of attached ticks and also on the total number, but the results were usually about the same by both methods. Most results presented in this paper are based on the total number. The per cent repellency was computed on the basis of the number of ticks on the untreated check.

The formulations and the dosages used are given in table 1. The ingredients identified by code numbers are as follows:

9	Indalone
63	Diphenyl carbonate
523	Benzyl benzoate
671	Dibutyl adipate
1805	*p*-Tolyl benzoate
2065	Hendecenoic (undecylenic) acid
2484	*N*-Butylacetanilide
3341	*N*-Isopropylacetanilide
3775	2-Butyl-2-ethyl-1,3-propanediol
4145	*N*-Butyl-4-cyclohexene-1,2-dicarboximide
4202	Hexyl mandelate
5524	*N*-Propylacetanilide
16807	Lindane

The following repellents were used in aerosols at the dosages indicated:

	Grams per Square Foot
Indalone (9)	1.41
Dimethyl carbate (3916)	1.57
Ethyl *beta*-phenylhydracrylate (6216)	1.49
2-Butyl-2-ethyl-1,3-propanediol (3775)	0.53

[1] This work was conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine under funds allotted by the Department of the Army to the Bureau.

[2] The authors acknowledge the assistance of the many members of the Orlando, Fla., laboratory, who took an active part in the testing, and of W. V. King and W. C. McDuffie, who helped plan the study.

The first three aerosols contained 20 per cent of repellent, and 40 per cent each of methylene chloride and Freon-12 (dichlorodifluoromethane). The fourth contained 5 per cent each of 2-butyl-2-ethyl-1,3-propanediol and Velsicol AR-50 and 45 per cent each of methylene chloride and Freon-12.

TESTS WITH INDIVIDUAL COMPOUNDS.—Initial tests with 44 repellents were made by impregnating one to four uniforms with acetone solutions of the compounds and testing weekly for 2 or 3 weeks. Most of the compounds had not previously been tested in the field, but Indalone, *N*-butylacetanilide, and hexyl mandelate were included as standards of comparison. Twenty-one repellents that appeared promising in these or previous tests (Cole & Smith 1950) were tested further by impregnating uniforms with emulsions containing them, and four repellents were also applied in aerosols. A few of the uniforms that were 90 per cent effective during the first 3 weeks were tested once a week for 2 or 3 additional weeks. Selection was made on the basis of the performance of the individual uniform, even though the average effectiveness of all uniforms with the same treatment might be less than 90 per cent. The results obtained during the first 3 weeks after treatment are presented in table 2, and those obtained during the second 3 weeks are given in table 3.

In the tests with acetone solutions the outstanding compounds were *N*-butylacetanilide (2484), *N*-propylacetanilide (5524), and 1-benzylcylohexanol (5558), which gave average repellencies of 97 to 98 per cent, and were at least 94 per cent effective in all individual tests. Twelve other compounds showed average repellencies of 90 to 95 per cent. There was a wide range of effectiveness in individual tests with most of the compounds, and the lowest repellency sometimes was observed in the first week after treatment.

In the tests with emulsions *N*-butylacetanilide (2484), *N-propylacetanilide* (5524), and 1-benzylcyclohexanol (5558) were again 97 to 98 per cent effective, but the last was so irritating to the skin that it was dropped from further consideration. Several other compounds were equally effective in emulsions—namely, *alpha*-butoxy-*N*-cyclohexylacetamide (614), dicyclopentyl ester of succinic acid (6054), *N*-isopropylacetanilide (3341), and methyl propyl ester of bicyclo [2.2.1]-5-heptene-2,3-dicarboxylic acid (8439). Slightly less effective compounds were hendecenoic (undecylenic) acid (2065), Indalone (9), *N*-butyl-4-cyclohexene-1,2-dicarboximide (4145), dimethyl carbate (3916), hexyl mandelate (4202), dibutyl adipate (671), and 2-[2-(2-ethylhexyloxy) ethoxy]ethanol (300). The last material was irritating to the skin. Five repellents

Table 1.—Formulation of repellent mixtures and rate of application to uniforms.

Mixture No.	Active Ingredients: Code No.	Active Ingredients: Dosage (Grams per Square Foot)
MT-1	9	1.0
	523	1.0
MT-2	4202	1.0
	523	1.0
M-1955	3775	1.0
	9	1.0
M-1956	3775	1.0
	2484	1.0
M-1957[1]	3775	1.07
	63	0.80
	9	1.33
M-1960	3775	1.07
	2484	1.07
	523	1.07
M-1961	3775	1.0
	523	1.0
M-1962	2484	1.0
	523	1.0
M-1981[1]	3775	1.33
	63	.53
	2484	1.33
M-1991	3775	1.06
	2484	1.06
	523	1.06
	1805	.35
M-2001[2]	3775	1.33
	2484	1.33
	1805	.53
M-2002[2]	3775	1.33
	9	1.33
	1805	.53
M-2003[2]	2484	1.0
	1805	0.5
M-2004[2]	3775	1.33
	4202	1.33
	1805	.53
M-2005[2]	3775	1.33
	5524	1.33
	1805	.53
M-2006	3775	1.07
	5524	1.07
	523	1.07
M-2007	3775	1.06
	5524	1.06
	523	1.06
	1805	.35
M-2008[2]	3775	1.33
	2065	1.33
	1805	.53
M-2033	3775	1.07
	3341	1.07
	523	1.07
M-2034	3775	1.07
	4145	1.07
	523	1.07
M-2035	3775	1.07
	2065	1.07
	523	1.07
M-2036	4145	1.07
	2484	1.07
	523	1.07
M-2037	2065	1.07
	2484	1.07
	523	1.07
M-2038	3775	1.07
	2484	1.07
	4145	1.07
M-2039	3775	1.07
	2484	1.07
	2065	1.07
M-2040	4145	1.07
	2484	1.07
	2065	1.07
M-2041	3775	0.66
	2484	.66
	523	.66
	4145	.66
	2065	.66
M-2059	3775	1.06
	2484	1.06
	523	1.06
	16807	.04
M-2060	3775	1.07
	671	1.07
	523	1.07
M-2061	3775	1.07
	2484	1.07
	671	1.07

[1] Contained 30% of xylene.
[2] Contained 18% of xylene.

Table 2.—Effectiveness of individual repellents as clothing impregnations against lone star ticks 2 or 3 weeks after treatment.

CODE NO.	REPELLENT	NUMBER OF TESTS	PER CENT REPELLENCY	
			Range	Average
	In Acetone Solutions			
2484	Acetanilide, *N*-butyl-	6	94–100	98
5524	Acetanilide, *N*-propyl-	7	95–100	98
5558	Cyclohexanol, 1-benzyl-	3	96– 99	97
3341	Acetanilide, *N*-isopropyl-	6	80–100	95
6555	Acetoacetamide, *N,N*-dibutyl-	6	78–100	95
12041	*p*-Acetotoluidide, *N*-ethyl-	6	79–100	95
12135	4,6-Decanediol, 5-ethyl-	6	90– 99	95
5949	2,4-Nonanediol	3	91– 97	94
614	Acetamide, *alpha*-butoxy-*N*-cyclohexyl-	6	71–100	94
4262	4-Morpholineacetic acid, isobornyl ester	9	82– 98	93
6351[1]	Caproic acid, 5-hydroxyamyl ester	3	91– 93	92
671	Adipic acid, dibutyl ester	3	90– 95	92
6054	Succinic acid, dicyclopentyl ester	3	83– 98	92
9	Indalone	7	80– 98	92
6270	Crotonic acid, 1,3-propanediol diester	6	72– 96	90
6021	Suberic acid, diethyl ester	6	69– 98	88
2971	Succinimide, *N*-amyl	9	71–100	88
4202	Mandelic acid, hexyl ester	12	58– 99	88
6052	Adipic acid, dipropyl ester	3	81– 92	87
1766	Phthalic acid, diisopropyl ester	5	78– 93	86
1769	Terpinol, diacetate	8	45–100	86
2065	Hendecenoic (undecylenic) acid	6	73– 98	86
373	Ethanol, 2-(2-cyclohexyloxyethoxy)-	6	67– 94	85
949	Cinnamyl alcohol	6	63– 98	85
6485	Adipamic acid, *N,N*-dipropyl-, methyl ester	6	67– 94	84
4790	Caprylic acid, fenchyl ester	5	59–100	83
6515	2-Cyclohexene-1-carboxylic acid, 2-methyl-4-oxo-6-propyl-, ethyl ester	5	67– 98	82
7159	5-Decyne-4,7-diol, 2,4,7,9-tetramethyl-	5	58– 95	82
6402	Succinamic acid, *N,N*-diisobutyl-, methyl ester	9	32– 96	82
7790	Acetoacetic acid, *alpha*-benzyl-, ethyl ester	5	66– 91	78
4162	Caprylic acid	6	44– 98	78
2320	Levulinic acid, benzyl ester	5	70– 95	77
2069	Benzaldehyde, 3,4-diethoxy-	2	74– 78	76
7043[1]	Benzoic acid, 3-butynyl ester	1	76	76
9485	Salicylamide, *N*-butyl-	4	55– 90	75
6168	Succinamic acid, *N,N*-diethyl-, propyl ester	4	64– 93	75
5831	Acetic acid, (cyano)phenyl-, ethyl ester	6	53– 93	74
6484	Adipamic acid, *N, N*-diisopropyl-, methyl ester	4	54– 83	73
3775	1,3-Propanediol, 2-butyl-2-ethyl-	4	45– 86	72
2064	Benzoic acid, hexyl ester	5	47– 84	64
6226	Cyclohexaneacetic acid, 1-hydroxy-, butyl ester	5	0– 99	58
7198	Hydrocinnamic acid, *alpha,beta*-epoxy-*beta*-methyl-, 2-ethoxyethyl ester	4	29– 82	54
6107	Anisic acid, isobutyl ester	4	0– 80	47
5533	*m*-Dioxane, 4-(*p*-methoxyphenyl)-5-methyl-	5	0– 79	42
	In Emulsions			
2484	Acetanilide, *N*-butyl-	12	88–100	98
5524	Acetanilide, *N*-propyl-	12	91–100	98
614	Acetamide, *alpha*-butoxy-*N*-cyclohexyl-	12	92–100	98
6054	Succinic acid, dicyclopentyl ester	9	93–100	98
3341	Acetanilide, *N*-isopropyl-	6	90–100	97
8439	Bicyclo [2.2.1]-5-heptene-2,3-dicarboxylic acid, methyl propyl ester	8	94–100	97
5558[1]	Cyclohexanol, 1-benzyl-	3	92–100	97
2065	Hendecenoic (undecylenic) acid	9	84– 99	93
9	Indalone	9	76–100	91
300[1]	Ethanol, 2-[2-(2-ethylhexyloxy)ethoxy]-	4	78–100	91
4145	4-Cyclohexene-1,2-dicarboximide, *N*-butyl-	7	76– 98	91
3916	Dimethyl carbate	5	73– 99	90
4202	Mandelic acid, hexyl ester	12	78–100	89

[1] Too irritating to the skin for general use.

Code	Repellent	Number of Tests	Per Cent Repellency	
			Range	Average
671	Adipic acid, dibutyl ester	9	55–100	87
6052	Adipic acid, dipropyl ester	3	77– 91	84
4262	4-Morpholineacetic acid, isobornyl ester	6	60–100	80
3775	1,3-Propanediol, 2-butyl-2-ethyl-	5	66– 95	79
2711	Isobutyric acid, 2-phenoxyethyl ester	5	54– 84	70
1769	Terpinol, diacetate	6	42– 85	69
329	Phthalic acid, diethyl ester	4	28– 88	66
6216	Hydracrylic acid, *beta*-phenyl-, ethyl ester	5	35– 86	65
	In Aerosols			
6216	Hydracrylic acid, *beta*-phenyl-, ethyl ester	3	83– 93	87
3916	Dimethyl carbate	3	73– 98	84
3775	1,3-Propanediol, 2-butyl-2-ethyl-	2	73– 85	79
9	Indalone	3	9– 29	22

were more than 90 per cent effective during the second 3 weeks after treatment —namely, *alpha*-butoxy-*N*-cyclohexylacetamide (614), *N*-propylacetanilide (5524), *N*-butylacetanilide (2484), dicyclopentyl ester of succinic acid (6054) (as an emulsion only), and methyl ester of *N*,*N*-diisobutylsuccinamic acid (6402).

Aerosol treatments of ethyl *beta*-phenylhydracrylate (6216), 2-butyl-2-ethyl-1,3-propanediol (3775), and dimethyl carbate (3916) were about as effective as emulsion impregnations, although the rate of application was lower. An aerosol treatment of Indalone (9) was ineffective.

EFFECTIVENESS OF VARIOUS FORMULATIONS AND METHODS OF APPLICATION.—A series of tests was conducted to compare the effectiveness of emulsions and several solutions for impregnating uniforms with Indalone, *N*-butylacetanilide, and hexyl mandelate. Acetone, gasoline, and xylene were used as the solvents. Uniforms sprayed with the undiluted repellents were also included in the tests. Two uniforms with each treatment were tested once a week for 3 weeks. The average repellencies given in table 4 indicate no marked differences in the effectiveness of the various methods of application.

TESTS WITH MIXTURES.—Compounds that had shown promise against ticks were combined with outstanding repellents against mosquitoes, fleas, or chig-

Table 3.—Effectiveness of individual repellents as clothing impregnations against lone star ticks 4 to 6 weeks after treatment.

Code No.	Repellent	Number of Tests	Average Per Cent Repellency
	In Acetone Solutions		
6402	Succinamic acid, *N*,*N*-diisobutyl-, methyl ester	1	91
6555	Acetoacetamide, *N*,*N*-dibutyl-	2	87
12041	*p*-Acetotoluidide, *N*-ethyl-	3	85
6054	Succinic acid, dicyclopentyl ester	2	82
6021	Suberic acid, diethyl ester	2	76
	In Emulsions		
614	Acetamide, *alpha*-butoxy-*N*-cyclohexyl-	2	98
5524	Acetanilide, *N*-propyl-	2	96
2484	Acetanilide, *N*-butyl	8	94
6054	Succinic acid, dicyclopentyl ester	6	93
671	Adipic acid, dibutyl ester	4	89
9	Indalone	3	83
2065	Hendecenoic (undecylenic) acid	3	80
4145	4-Cyclohexene-1,2-dicarboximide, *N*-butyl-	3	79
8439	Bicyclo [2.2.1]-5-heptene-2,3-dicarboxylic acid, methyl propyl ester	6	76

Table 4.—Relative effectiveness of various formulations and methods of application for treating uniforms as protection against the lone star tick.

FORMULATION AND METHOD OF APPLICATION	AVERAGE PER CENT REPELLENCY		
	Indalone	*N*-Butyl-acetanilide	Hexyl Mandelate
Impregnated:			
Emulsion	90	97	88
Solutions:			
Acetone	92	98	88
Gasoline	90	99	94
Xylene	88	99	91
Sprayed:			
Undiluted repellent	87	99	91

gers, in an effort to develop a general-purpose mixture that would be effective against all these species. Some of the compounds were especially effective against several of these groups of arthropods. Seven mixtures were tested in 1949, and the three most effective ones were retested in 1950, together with 11 new mixtures. One to four uniforms treated with emulsions of each mixture were tested once a week for 2 or 3 weeks after treatment. The results are given in table 5.

In the 1949 series, three mixtures—M-1981, M-1956, and M-1960—that included *N*-butylacetanilide (2484) as the principal tick repellent were at least 90 per cent effective, whereas those containing Indalone (9) or hexyl mandelate (4202) were not more than 80 per cent effective. The mixtures selected for testing in 1950 therefore included these three mixtures and modifications of them made by substituting for one or more of the ingredients.

Table 5.—Effectiveness of repellent mixtures against lone star ticks.

MIXTURE NO.	NUMBER OF TESTS	PER CENT REPELLENCY	
		Range	Average
	Tests in 1949		
M-1981	6	93–98	96
M-1956	6	91–99	95
M-1960	6	68–99	90
MT-2	4	75–87	80
M-1957	5	43–98	72
MT-1	3	60–70	66
M-1961	4	16–76	48
	Tests in 1950		
M-1981	6	97–100	99
M-1956	12	95–100	98
M-2001	12	95–100	98
M-1960	12	92–100	97
M-2003	9	84–100	97
M-1962	9	92–100	96
M-1991	12	87–100	96
M-2002	6	80–98	92
M-2005	3	80–92	88
M-2008	6	82–97	88
M-2007	3	79–91	84
M-2006	3	78–87	81
M-2004	6	64–91	80
M-1955	6	52–93	76

In the 1950 series seven mixtures that contained *N*-butylacetanilide (2484) as the principal tick repellent were 96 to 98 per cent effective, whereas seven others that contained Indalone (9), *N*-propylacetanilide (5524), hendecenoic (undecylenic) acid (2065), or hexyl mandelate (4202) showed average repellencies of 76 to 92 per cent.

Four of the outstanding mixtures—M-1981, M-1991, M-2001, and M-2003—were later dropped from consideration when additional toxicological studies indicated they would be unacceptable for the intended use, and two others—M-1956 and M-1962—failed to provide protection against some other arthropods. M-1960 was effective against chiggers, three species of mosquitoes, two species of fleas, and two additional species of ticks, and was also indicated in toxicological studies to be acceptable for the treatment of clothing of military personnel. Its safety for unsupervised civilian use has not been determined.

Efforts were continued to increase the effectiveness of the mixture against one or more species without decreasing its effectiveness against others. Tests were conducted in 1952 with 14 mixtures, most of which were modifications of the M-1960 formula made by substituting for one or more of its ingredients. Three uniforms with each treatment were tested once each week for 6 weeks, after which 15 of those that were still most effective were worn for three 8-hour periods and then tested twice during the eighth week. The results are presented in table 6.

During the first 3 weeks there was little difference between the more effective treatments. The average repellency with 11 treatments, including M-1960, ranged from 97 to 99 per cent. During the second 3 weeks, and especially the fifth and sixth, distinct though often slight differences between the treatments became apparent.

Table 6.—Relative effectiveness of emulsions of repellent mixtures for impregnating uniforms against lone star ticks in 1952.

Mixture No.	Average Per Cent Repellency		
	1 to 3 Weeks	4 to 6 Weeks	8 Weeks
M-2059	99	98	97
M-2040	98	98	96
M-2039	98	98	92
M-2038	99	99	90
M-2061	99	97	—
M-1960	99	93	93[1]
M-2037	97	93	—
M-2033[2]	99	92	—
M-2060	98	91	—
M-2035	91	90	—
M-2036[2]	98	89	—
M-2041	99	87	—
M-2006	94	86	—
M-2034[2]	91	64	—

[1] Two replications.
[2] Irritating to the skin under sweating conditions.

The average repellency with five treatments was 97 to 99 per cent, whereas that with M-1960 and most of the other compounds dropped to 93 per cent or less. During the eighth week, after an intervening period of wear, mixtures M-2040 and M-2059 were distinctly better than the other mixtures. All the mixtures that were better than M-1960 contained *N*-butylacetanilide (2484).

Relative Repellency to Nymphs and Adults.—Data on the average numbers of attached and unattached nymphal and adult ticks on subjects wearing treated and untreated uniforms are given in table 7. Only treatments that showed a moderate degree of effectiveness (80 per cent in 1949 and 50 per cent in 1950) were included in the computations of the averages for treated uniforms.

The repellents were generally more effective against nymphs than against adults, and slightly more effective against males than against females. As nymphs were more numerous than adults, the repellency recorded in the preceding tables for the various treatments usually reflects the repellency to nymphs, and is slightly higher than would be obtained against adult ticks. On the other hand, the repellency on the basis of attached ticks was generally greater than that on the basis of unattached ticks. Therefore, the actual protection from bites would be slightly greater than the indicated repellency for any treatment.

Summary.—Field tests with clothing treated with selected tick repellents were conducted during the summers of 1949, 1950, and 1952 in South Carolina and Georgia in areas heavily infested with nymphs and adults of the lone star tick, *Amblyomma americanum* (L.). The best repellents in the early tests were later combined with outstanding mosquito, chigger, and flea repellents to provide an all-purpose mixture.

Forty-four individual compounds were tested in acetone solutions and 21 in

Table 7.—Relative abundance of different stages of ticks, the general effectiveness of repellents against each stage, and the relative effectiveness based on attached and unattached ticks.

Stage of Tick	Treated Uniforms			Untreated Uniforms			Per Cent Repellency[1]	
	Number of Tests	Average number of ticks		Number of Tests	Average number of ticks			
		Attached	Unattached		Attached	Unattached	Attached	Unattached
				1949 Tests				
Nymphs	257	1.0	9.8	52	17.3	140.9	94	93
Adults:								
Males	257	0.5	1.1	52	6.0	8.9	92	88
Females	257	.4	1.1	52	5.7	8.4	93	87
				1950 Tests				
Nymphs	326	0.6	5.5	66	7.1	83.7	92	93
Adults:								
Males	326	.7	2.5	66	4.3	13.7	83	82
Females	326	.8	2.5	66	3.9	11.1	81	78

[1] Computed from the difference in the numbers of ticks on treated and untreated uniforms (unattached) or attached to subjects wearing such uniforms.

emulsions. The outstanding repellents were *N*-butylacetanilide, *N*-propylacetanilide, *alpha*-butoxy-*N*-cyclohexylacetamide, dicyclopentyl succinate, *N*-isopropylacetanilide, and the methyl propyl ester of bicyclo[2.2.1]-5-heptene-2,3-dicarboxylic acid. Slightly less effective were hendecenoic (undecylenic) acid, Indalone, *N*-butyl-4-cyclohexene-1,2-dicarboximide, dimethyl carbate, hexyl mandelate, and dibutyl adipate.

Clothing treated with aerosols of three repellents was as effective as clothing treated with emulsions or solutions of the same compounds, but an aerosol treatment with Indalone was ineffective.

There was no marked difference in the effectiveness of Indalone, *N*-butylacetanilide, and hexyl mandelate when applied to clothing in emulsions, in solutions of acetone, gasoline, or xylene, or in a spray of the undiluted compounds.

The most effective all-purpose mixtures were those containing *N*-butylacetanilide as the tick repellent. One of the outstanding mixtures, designated M-1960, contained 30 per cent each of *N*-butyl-acetanilide, 2-butyl-2-ethyl-1,3-propanediol, and benzyl benzoate, and 10 per cent of an emulsifier, Tween 80. This mixture was indicated in toxicological studies to be acceptable for the treatment of clothing of military personnel. Its safety for civilian use has not been determined.

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The Insect Pest Situation in Israeli Agriculture

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In June 1952, the writer arrived in Israel on an assignment under the Food and Agriculture Expanded Technical Assistance Program to advise and assist that Government in insect control. The Division of Plant Protection is headed by Dr. J. Peleg, and consists of a staff of seven entomologists and four pathologists. There is also a section of weed control, and another for the control of rodents, birds and wasps. In addition, there is a well-equipped chemical laboratory for making chemical analyses of insecticides and spray residues and for carrying out fumigation experiments.

The plant quarantine service has men stationed at Haifa and Lydda in order to prevent the importation of new pests. Their job is to destroy or fumigate all suspicious material that may carry new pests. During the past year, an effective organization has been built up to cope with the locust problem, which is now threatening.

The Division of Plant Protection is alerted to the introduction of the latest modern spray equipment, mist blowers, low volume spray machinery and airplanes. The personnel occupy themselves primarily with extension work among the farmers, but they also carry out field investigations with insecticides and fungicides. The biological and more basic research work is carried out at the Rehovoth Experiment Station.

The state of Israel is undergoing rapid growth and development. The introduction of new plants in new areas, and the intensive system of agriculture demands a ready solution of the insect problems that are constantly arising. Several million dollars worth of insecticides and fungicides are used annually. Cryolite is especially popular, over 600 tons being used a year. The country is small with a wide variety of climatic factors. The summer months are dry but rain falls during the winter months. The Jordan Valley is

tropical, the coastal plains subtropical and the mountainous areas temperate.

Citrus is the major exportable asset of Israel and before World War II there were 75,000 acres. The most important insects of citrus are the Florida red scale, *Chrysomphalus aonidum* (L.) (known locally as the black scale); the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.) and the Mediterranean fruit fly, *Ceratitis capitata* (Wied.). Scale insects are well controlled with highly refined petroleum oil sprays, while the citrus rust mite is satisfactorily controlled by sulphur dust, although sulphur is scarce.

MEDITERRANEAN FRUIT FLY.—Control of this pest is still an unsolved problem although considerable progress has been made. The presence of this insect limits the production of oranges to the winter months when the fly is usually not active. During the season of 1952–53, a large-scale field experiment was financed by the Citrus Board and carried out under the direction of Dr. A Grunberg. The following formulations were tested at Ein-Harod, Nes-Ziona, Ramleh and Chazor: Emulsion sprays containing DDT or methoxychlor; suspension sprays containing DDT, dieldrin, lindane, or methoxychlor.

In all the treatments, the insecticides were applied at the rate of 2 kg. of active ingredients per dunam (0.25 acre) in 100 litres of water at Ein-Harod. The methoxychlor-suspension was applied by airplane. Treatments were applied the first week in October and at Chazor, a second application was made October 16. As a check on effectiveness, fallen fruit under 40 trees in each plot was counted, and biological tests were carried out to determine the toxicity of spray residues on leaves. For this purpose, larvae of yellow-fever mosquito, *Aedes aegypti* (L.) and adults of *Drosophila* sp. and the granary weevil, *Sitophilus granarius*, (L.) were employed.

Samples of leaves were collected at various intervals in orchards sprayed October, 1952, and brought to the laboratory. From each sprayed plot 1 square inch from five leaves were used and placed in cups with 50 cubic centimeters of water. The water was stirred a few times and after 10 minutes the leaves were removed and mosquito larvae added. Observations were then made as to the time required for mortality as shown in table 1. From leaves collected November 6, the lindane was no longer toxic. Dieldrin and DDT suspension showed 100 per cent kill in 24 hours, while methoxychlor gave only 60 per cent. By December 10, dieldrin was still very toxic with 100 per cent kill. DDT emulsion gave a kill of 70 and methoxychlor suspension 50 per cent.

Table 1.—Toxicity tests to *Aedes aegypti*.

INSECTICIDE	PER CENT DEAD IN 24 HRS.	
	November 6	December 10
Dieldrin	100	100
DDT emulsion	60	70
DDT suspension	100	0
Methoxychlor emulsion	60	0
Methoxychlor suspension	60	50
Lindane	0	0

Tests were also conducted to determine the toxicity of the pure materials. Methoxychlor wettable powder was toxic to mosquito larvae at a dilution of 1 to 20,000,000, while dieldrin gave a kill at 1 to 500,000,000.

FIELD OBSERVATIONS IN 1952–53.—The week of December 3–9 was very warm and resulted in a rapid buildup of the Mediterranean fruit fly. At Lydda, some of the trapping bottles had up to 200 adults per bottle. South of Rehovoth, adults were present in injurious numbers, and in the latter part of December much of the fruit was already infested. One of the experimental orchards was located at Chazor where perhaps half of the oranges and grapefruit were on the ground in the untreated plots. In the sprayed plots, there was no fruit on the ground and very few stings were observed. Many of the oranges in the check plot had as many as 12 stings or egg-laying punctures, and full-grown larvae were also present in the grapefruit. Due to the unusually warm season, many of the orchards suffered heavy damage from this insect. In a normal year, flies are not present in December. Under heavy fly populations as in the present season, the growers would like to apply control measures, but there are not enough sprayers in the country to cover the orchards in a week or two. If enough planes were available, a 50-per cent wettable

powder could be applied within a few days to most of the orchards. However, more data must be obtained with dusts applied by airplane, and every effort must be made to determine the effectiveness of dust applications in emergencies, when this insect threatens.

RESULTS.—On October 6, 1952, methoxychlor emulsion was applied at Chazor at the rate of 2 kg. per dunam. Counts were made as to the number of ovipositing punctures on 33,800 fruits. One of the plots received two treatments in the fall and one plot received one treatment in the fall and one treatment in the spring. As noted in table 2, excellent results were obtained. Dieldrin was more effective than methoxychlor. The best results were obtained with lindane which reduced infestation to 0.16 per cent. These tests should be repeated, since, in the biological tests, lindane was not as effective as dieldrin.

Table 2.—Results of treatments against the Mediterranean fruit fly.

MATERIAL	NO. OF FRUITS	PER CENT INFESTED IN	
		Treated	Untreated
At Chazor			
Methoxychlor emulsion[1]	33,800	0.41	81.7
Methoxychlor emulsion	13,000	8.17	81.7
At Nes-Ziona			
Methoxychlor emulsion	13,000	0.41	12.5
Methoxychlor suspension	13,000	0.45	12.5
Dieldrin suspension	13,000	0.21	12.5
Lindane suspension	13,000	0.16	12.5

[1] Two applications.

Heretofore, the fruit fly was a limiting factor in the production of citrus in Israel especially in warm winters, and on late varieties such as the Valencia (Rivnay 1950, Ebeling 1950). The results of the experiments as shown in table 2 indicate that the use of methoxychlor or dieldrin give good control. This being the case, the growing of late varieties such as Valencia should be encouraged. This will extend the shipping season, and make the production of citrus fruits more profitable.

IMPORTANCE OF FUMIGATION.—Recent tests using ethylene dibromide (7 grams per cubic meter) as a fumigant have given excellent results in the control of the larvae in the fruit, giving 98 per cent control. Fumigation is much more economical than spraying, and gives another weapon in the control of this insect, especially for the export trade. Fumigation cannot replace spraying under conditions of heavy infestation, however, Ethylene dibromide, when used with 18 gms. of nitrogen trichloride for the control of diseases, produces a synergistic effect against the fruit fly.

OTHER INSECTS.—*Olive fruit fly, Dacus oleae (Gmel.).*—Control measures are lacking for this insect. Olives are important in the agriculture of Israel, as 150,000 dunams are being grown, mostly in the hill-country. The early large-fruited varieties such as Merhavia are more readily attacked than the small-fruited Souri.

Experiments on control were carried out by Dr. I. Peretz of the Division of Plant Protection, in 1951 with:

(1) 5 per cent DDT+2 per cent molasses.
(2) 5 per cent methoxychlor+2 per cent molasses.
(3) Dieldrin 0.3 per cent.

Each tree received 20 liters of spray material and active ingredients of 50 grams, except dieldrin which received 15 grams. Four treatments were given beginning the first week in June. The results of these treatments were encouraging.

Sugar-beet weevil, Lixus juncii Boh.—This insect is one of the limiting factors in the cultivation of sugar beets in Israel (Marcovitch 1952). In some years, the damage may be as high as 50 per cent with an average of 20 per cent. In 1952, larvae, pupae and adults were abundant in July in the Huleh area. The larvae frequently cause a rot to develop in the beets, while the adults attack the leaves which wither and fall to the ground. The beetle has been known as a pest of fodder beets for many years. The second generation is particularly injurious in the month of July

Previous experimental work, indicated that BHC (0.5 per cent of 6.5 per cent gamma isomer) is effective against this insect, and it will be tested further. Against the first generation, the treatments are made the middle of February and against the second generation, about the middle of June. Preliminary trials with an emulsion spray of parathion were very promising, since it killed the larvae in the stems.

An interesting development is the growing of sugar beets in the fall and winter on land that is used for fish ponds in summer. The sugar beets make a wonderful growth on the fertile soil that is completely free of

weeds. Frequently these beets are attacked by *Prodenia litura* (F.) or *Agrotis ypsilon* (Rott.), and the question arises as to the effect of DDT or other insecticides on the growth of fish in the ponds. It appears that cryolite would be a safe insecticide, since the waters in Israel have a high calcium content. The formation of calcium fluoride would tend to neutralize any toxicity from the cryolite residues.

Prodenia litura (F.).—This insect is one of the more injurious pests in Israel and attacks a wide variety of crops including many legumes, potatoes, sugarbeets, cotton, flowers and many plants in nurseries. A ten per cent sodium fluosilicate bait or a cryolite dust will give control if repeated 2 or 3 times. The past year, a 0.3 per cent dieldrin spray of a 50 per cent wettable powder gave excellent control on beans and peanuts when used at the rate of 600 grams per acre. Heavy infestations required two treatments.

Spiny boll worm, Earias insulana (Bdv.).—Cotton is not grown commercially at present in Israel. In an experimental patch, this insect proved to be a major pest, destroying about 90 per cent of the squares and bolls.

It is planned to test endrin which has been reported to be very effective in Iraq when used at the rate of $\frac{1}{4}$ to $\frac{1}{2}$ pound per acre.

Oriental hornet, Vespa orientalis L.—One of the most destructive insects in the Middle East is the oriental hornet (Rivnay 1949). It attacks grapes and some vineyards suffer as much as 50 per cent damage. In apiaries, it kills bees and entire apiaries have been known to be destroyed. It also injures dates and other fruits. Young trees are frequently badly damaged through the destruction of the bark. Mr. M. Raskin, hornet expert, has been appointed to cope with this pest and advises farmers in methods of control. He recommends that the queens be caught and killed in the spring. For the nests in the ground, he recommends the use of calcium cyanide. Trapping with a bait composed of meat and thallium sulfate is also advised.

Grape Insects.—The two most important insects attacking grapes are a grape berry moth, *Polychrosis botrana* (Schiff.) the citrus mealy bug, *Pseudococcus citri* Risso. The presence of these pests forces early harvest and thus reduces the sugar content. The work of Dr. I. Peretz showed that they could be controlled by treatments with *Kryocide*[1] and DDT.

The best results were obtained with one application of *Kryocide* using 1.5 kg. per dunam and two applications of DDT. These treatments gave 97 per cent clean fruit, while the checks had only 24 per cent clean. At harvest time, there was 0.8 p.p.m. of fluorine present and 0.3 p.p.m. of DDT. Where mealy bugs were present they were controlled by parathion. The control of these pests enabled the growers to harvest the grapes 3 weeks later, and resulted in an increase of sugar content from 18 to 24 per cent.

Stored grain Insects.—The work on stored grain insects is being carried out by Mr. D. Kalderon who is making a survey of the various insects attacking the grain in storage on the farms. The most abundant insects present are the rice weevil, *Sitophylus oryzae* (L.), *Rhizopertha dominica* (Fabr.) and the confused flour beetle, *Tribolium confusum* Duv. *Trogoderma granarium* Everts is also present in serious numbers in the Jordan Valley. The various methods of grain storage are being studied. When feasible, fumigation with ethylene dibromide at the rate of 80 to 100 grams per cubic meter is recommended. Where proper control measures are not taken, the damage may frequently amount to 30 per cent. Birds such as the starling are also of considerable importance, by eating the grain and tearing the sacks.

Fig borer, Batocera rufomaculata Deg.—This species appears to be a new pest in Israel and was found by Dr. J. Bytinske, also of the Division of Plant Protection, in the Haifa area in 1951. It is a very large insect, the adult beetle being over 2 inches long. The larvae live in the trunks of the fig tree, feed on the cambium, and eventually kill the tree. This insect probably came to Israel from Africa, where it feeds on mango and a large number of other trees.

Mole crickets, Gryllotapla gryllotalpa (L.).—A very heavy infestation of mole crickets was found at Kfar Azar on December 2, 1952. Potatoes were completely destroyed and lettuce and spinach suffered badly. For control, 2-per cent of aldrin was applied by Dr. Peretz at the rate of 10-kg. per dunam and worked into

[1] Sodium fluoaluminate of Pennsylvania Salt Mfg. Co.

the soil. An examination on December 23 showed that the aldrin gave excellent control. Some of the plots were so heavily infested that two applications were necessary for good control. BHC was not so effective as aldrin.

Codling moth, Carpocapsa pomonella (L.)—Due to the warm climate, there are five or six generations of codling moth on apple. In order to keep this pest in check, 8 to 10 treatments of DDT and *Kryocide* are required at 10 to 14 day intervals. The use of DDT, however, often results in a mite problem for which sulphur is used. Tests with Aramite for control of mites are contemplated.

The leopard moth, Zeuzera pyrina (L.).—This insect is a serious pest of apple and olive trees. Mechanical methods such as inserting a wire in the tunnels are used in its control. Sprays of *Kryocide* at the end of the summer are also effective.

Capnodis spp.—In previous years, larvae of capnodis were a limiting factor in the production of stone fruits, by girdling the trees. Hand methods were not very successful. The adults can be effectively poisoned by the use of *Kryocide* by spraying during the months of April to July.

Summary.—There is a well organized Division of Plant Protection in Israel to cope with insect and disease problems. Citrus is the major exportable asset, the most important insects of which are the Florida red scale, *Chrysomphalus aonidum* (L.) the citrus rust mite, *Phyllocoptruta oleivora*, (Ashm.), and the Mediterranean fruit fly, *Ceratitis capitata* (Wied.). Field tests on the latter insect showed good control with dieldrin and lindane. For the export trade, fumigation with ethylene dibromide was developed.

On sugar beets, *Lixus juncii* Boh. is a serious pest. In preliminary trials, an emulsion of parathion gave promising results. Other important pests are the olive fruit fly, *Dacus oleae* (Gmel.); *Prodenia litura* (F.), and the spiny boll worm, *Earias insulana* (Bdv.) on cotton; the oriental hornet, *Vespa orientalis* L., a grape berry moth, *Polychrosis botrana* (Schiff.), the citrus mealy bug, *Pseudococcus citri* (Risso), the codling moth, *Carpocapsa pomonella* (L.), and *Capnodis spp.* on stone fruits.

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A Testing Procedure for Evaluating Liquid Sprays Against Cockroaches

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A review of the literature on the testing of liquid sprays against cockroaches by Woodbury (1938); Woodbury & Barnhart (1939); Parker & Campbell (1940); Campbell, *et al.*, (1941); McGovran & Fales (1942); Henderson (1943)[1]; McGovran, *et al.*, (1943); Hazard (1945); Bottimer (1945); and Anon. (1946) shows that a test procedure we have been using in our laboratory for the last 8 years may be of interest to workers concerned with cockroach sprays. The test method employs a stainless steel hoop and a modified Peet-Grady atomizer and is a practical or consumer-type test that approximates the application of liquid sprays with a hand sprayer. The procedure is called the "racetrack" test since affected cockroaches have a tendency to run around the base of the hoop.

The apparatus consists of a steel hoop

Paid paper.

[1] Henderson, L. S. 1943. A Roach Testing Method. Unpublished Report. U.S.D.A. Insecticide Testing Laboratory, Beltsville, Md.

32 inches in diameter and 3 inches high made of 0.040-inch stainless steel. The seam is welded, ground, and polished to make a smooth joint. The Peet-Grady atomizer is the DeVilbiss Special No. 5004 described by Anon. (1952) which has been modified to spray downwards by means of a bored metal block ($1\frac{1}{4}'' \times \frac{5}{8}'' \times \frac{5}{8}''$) with breather hole and threaded extension for the tube (Fig. 1). With this adapter, the eductor tube of the atomizer is parallel with the spray nozzle rather than perpendicular to it. The Peet-Grady atomizer was designed as a precision sprayer to simulate conventional hand sprayers and to provide better control of dosage and dispersal of spray.

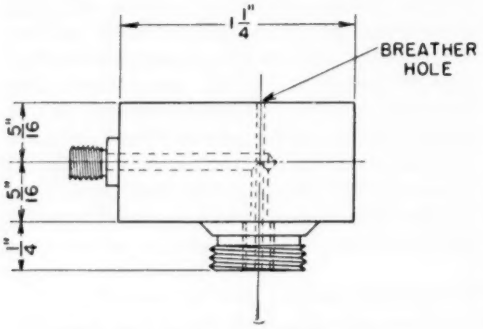

FIG. 1.—Profile sketch of adapter for Peet-Grady atomizer.

During application of spray, the insects are confined by the hoop on nonglazed absorbent gray bogus paper. The paper is renewed after each application. The inner wall of the hoop is lightly greased with a vaseline-mineral oil mixture (50:50 by volume) which prevents the cockroaches from climbing up the hoop. Usually 20 American, oriental, or German laboratory-reared cockroaches[2] are placed in the ring. The three species are often placed in the ring and sprayed at the same time to speed the testing program. A dosage of 6 or 12 ml. at a pressure of $12\frac{1}{2}$ p.s.i.g. is applied with the modified Peet-Grady atomizer. At times 18- and 24-ml. dosages are used. We consider the 6- and 12-ml. dosages to be equivalent to usual applications as made in the home against German cockroaches, and the 18- and 24-ml. dosages to be exceptionally heavy. The nozzle of the atomizer is held about 20 inches from the paper, and the gun is moved in a circular fashion so that the entire area within the hoop is sprayed. The object is to distribute the spray evenly over the area enclosed by the hoop without making any special effort to wet the cockroaches. With practice, the spray can be applied so that very little falls outside the hoop. One technician does all the spraying to minimize differences in technique. The tests are undertaken either in a Peet-Grady chamber or a 1000-cubic foot aerosol chamber. In the aerosol chamber, an experienced operator can spray three hoops each about 6 feet apart with the same spray one after the other. Observations have shown that drift of the spray from hoop to hoop under conditions of this test does not affect results. The cockroaches are exposed to the spray in the ring for 10 minutes, and 5- and 10- minute knockdown[3] counts are made. Timing of exposure to spray and knockdown observations are started on completion of spraying. The American and oriental cockroaches are picked up with the fingers, and the German cockroaches with forceps. An exhaust fan in the chamber removes any traces of spray mist after the 10-minute exposure. The test groups of the larger cockroaches are segregated in separate battery jars, and the smaller species in crystallizing dishes, and a 30-minute knockdown count is taken. The cockroaches are then held for 144 hours, and mortality[4] and morbidity[5] counts are made at 24, 48, 72, and 144 hours. In tests where there is no appreciable increase in mortality or morbidity after the 48-hour record, subsequent tests with the same series of sprays may be confined to 24- and 48-hour counts. The combined total of the per cent dead and moribund at 48 hours is our standard comparison figure. If the cockroaches are to be held for observation for more than 48 hours, each container is provided with a dog food nugget and a vial of water stoppered with absorbent cotton. The mortality has been found to be lower for German cockroaches when food and water are supplied during the first 48 hours.

[2] *Periplaneta americana* (L.), *Blatta orientalis* L., and *Blattella germanica* (L.) respectively.

[3] A cockroach is considered down when no longer capable of maintaining its normal upright position, normal locomotion, and shows evidence of paralysis. Ordinarily the larger cockroaches rest on their backs when down while the German cockroaches may be in any position.

[4] A cockroach is considered dead when it shows no voluntary movement even when gently probed.

[5] A moribund cockroach is one that is alive but partial paralyzed and capable of limited movement.

Eighteen to 20 individual tests may be conducted during one afternoon. Large nymphs of American, oriental, and German cockroaches, or adult males of the German cockroach, are ordinarily used. Untreated cockroaches, and cockroaches treated with base oil, are included as checks in each series. If desired, weight records are taken as a measure of cockroach size. Standard formulae or the Official Test Insecticide or OTI (approximately 100 mg. pyrethrins per 100 ml. base oil) (Anon. 1952) is always used along with the experimental sprays. Because of ease in handling and the low susceptibility of the American and oriental cockroaches to sprays at practical dosages, they are preferred to German cockroaches for test purposes. All oil base household spray formulations which were effective as contact insecticides against large nymphs of either the American or oriental cockroaches were also effective when used at similar dosages on large nymphs and adult males of German cockroaches; however, German cockroaches may be included at times for record purposes.

Although tables given in this paper do not include individual replicates, in general good agreement between replicates has been obtained with the above test procedure. Table 1 shows the results of the effects of varying amounts of Gulfspray Naphtha (a typical odorless-type household insecticide base oil, 0.78 sp. gr., and 380 to 480° F. boiling range) on large nymphs of American, oriental, and German cockroaches. It is interesting to note from table 1 that nymphs of the German cockroach are much more susceptible to the base oil alone than the nymphs of the larger cockroaches, and this fact must be considered when evaluating the effectiveness of toxicants in oil base sprays on the three species. McGovran & Fales (1942) showed that the adult female German cockroaches were more resistant to the base oil alone than the males or large nymphs.

Table 2 shows the results of tests with the OTI, and the above insecticidal base oil on American and oriental cockroach nymphs and adult male German cockroaches.

It can be observed from the test data that the adult male German cockroaches are more readily paralyzed with the OTI than the larger nymphs of the American and oriental cockroaches. However, based on the mortality records, the adult male German cockroaches appear to have about the same susceptibility to the OTI as the American cockroach large nymphs. The large nymphs of oriental cockroaches are definitely less affected by the OTI than either of the above two species. Note that the male adult German cockroaches are more susceptible to the base oil alone

Table 1.—Effect of different quantities of base oil against large nymphs of three species of cockroaches.

Cockroach Species	Ml. of Base Oil	Total No. of Cockroaches	No. of Tests	Average Per Cent Knockdown			Average Per Cent Dead and Moribund			
				5 m.	10 m.	30 m.	24 Hrs.	48 Hrs.	72 Hrs.	144 Hrs.
American	24	90	6	1	1	1	8	12	15	17
American	18	90	6	0	0	0	2	4	5	7
American	12	90	6	0	0	0	0	0	1	1
American	6	90	6	0	0	0	0	1	1	1
American	Untreated Check	70	4	0	0	0	0	0	0	0
Oriental	24	90	6	0	0	0	5	5	5	7
Oriental	18	90	6	0	0	0	2	2	3	3
Oriental	12	90	6	0	0	0	0	0	2	2
Oriental	6	90	6	0	0	0	0	0	0	0
Oriental	Untreated Check	70	4	0	0	0	1	1	1	1
German	24	90	6	36	41	55	89	91	91	91
German	18	90	6	36	34	36	60	63	68	68
German	12	90	6	7	4	7	15	15	24	27
German	6	90	6	0	0	0	5	8	8	10
German	Untreated Check	70	4	0	0	0	0	0	0	0

Average weight of 10 cockroaches before test: American—7.8 gm.; oriental—4.3 gm.; German—0.5 gm.

Table 2.—Effect of base oil and official test insecticide (OTI)[1] against three species of cockroaches.

Cockroach Species	Spray and Ml. Applied	Total No. of Cock-roaches	No. of Tests	Avg. Per Cent Knockdown			Avg. Per Cent Dead and Moribund			
				5 m.	10 m.	30 m.	24 Hrs.	48 Hrs.	72 Hrs.	144 Hrs.
American Large Nymph	12 ml. OTI	120	6	3	6	42	67	68	71	74
Oriental Large Nymph	12 ml. OTI	120	6	13	10	31	14	15	17	21
German Male Adult	12 ml. OTI	120	6	98	100	93	65	76	77	79
American Large Nymph	12 ml. Base Oil	140	7	0	0	1	1	1	2	2
Oriental Large Nymph	12 ml. Base Oil	140	7	1	1	1	0	0	0	0
German Male Adult	12 ml. Base Oil	140	7	0	1	0	16	30	35	37
American Large Nymph	Untreated Check	120	6	0	0	0	0	0	0	0
Oriental Large Nymph	Untreated Check	100	5	0	0	0	0	0	0	0
German Male Adult	Untreated Check	120	6	0	0	0	0	4	5	7

[1] Approximately 100 mg. pyrethrins per 100 ml.

than the large nymphs of the other two species. Parker & Campbell (1940) state that large nymphs of German cockroaches are less susceptible to pyrethrins-oil base sprays than the adult females. McGovran & Fales (1942), however, using a different technique found the adult female German cockroaches to be less readily affected by the afore-mentioned sprays than the adult males or large nymphs. McGovran *et al.* (1943) showed the adult female and large nymphs of German cockroaches to be less susceptible to a pyrethrins-oil base spray than the adult females and large nymphs of American cockroaches. It should be noted, however, that the pyrethrum spray used by them was a highly concentrated spray containing 500 mg. pyrethrins per 100 ml. solution which minimized action of the base oil.

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The Synergistic Action of Sulfoxide in Insecticide Sprays and Aerosols

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Sulfoxide has recently been accepted as a synergist for pyrethrum or allethrin in aerosol formulations. This material known chemically as *n*-octyl sulfoxide of isosafrole, was first reported as a synergist for pyrethrum in 1947 (Synerholm *et al.*). Other investigators have since made further tests with this material, particularly in comparison with the known synergists piperonyl butoxide and piperonyl cyclonene.

Starr (1950a) found that a spray containing 0.035 per cent of pyrethrins and 0.175 per cent of sulfoxide was as effective as the Official Test Insecticide (containing 0.125 per cent of pyrethrins) against cockroaches, and more effective against house flies. He also found an aerosol containing either allethrin or pyrethrins at 0.2 per cent plus DDT 2 per cent and sulfoxide 1 per cent to be above the Tentative Official Test Aerosol (pyrethrins 0.4 per cent plus DDT 2 per cent) in both 15-minute knockdown and 24-hour kill. Later Starr (1950b) stated that a spray containing 0.07 per cent of allethrin and 0.35 per cent of sulfoxide was rated as AA grade when tested by the official Peet-Grady method.

Gersdorff *et al.* (1952), reporting tests with kerosene sprays by the Campbell turntable method, stated that the synergism with sulfoxide was greater with pyrethrum than with allethrin mixtures and that it was as effective a synergist as piperonyl butoxide. Mallis *et al.* (1952) found that sulfoxide and piperonyl butoxide gave equal synergism with pyrethrum in kerosene sprays when tested by the large group Peet-Grady method. These two and piperonyl cyclonene were the most efficient pyrethrum synergists used in their tests.

This paper reports experiments in which the synergistic action of sulfoxide in sprays and aerosols was studied. In much of the work presented sulfoxide was compared with piperonyl butoxide. The sprays were dispensed with the standard Peet-Grady equipment and the aerosols with a laboratory dispenser. The test insects were the house fly, *Musca domestica* L., the common malaria mosquito, *Anopheles quardimaculatus* Say, the northern house mosquito, *Culex pipiens* L., and the American cockroach, *Periplaneta americana* (L.).

Sprays.—Sulfoxide and piperonyl butoxide were compared in sprays containing pyrethrum in one series and allethrin in another. In both sprays the ratio of insecticide to synergist was 1 to 10. House flies were used as the test insects.

Table 1 shows that the knockdown and kill were higher with the pyrethrum than with the allethrin sprays. The sprays containing sulfoxide were noticeably better in 5-minute knockdown and in mortality than those containing piperonyl butoxide. When combined with allethrin these synergists caused similar knockdown, but in contrast to the pyrethrum sprays, the spray containing piperonyl butoxide gave the higher mortality. *Butyl Cellosolve* was used as a cosolvent in the allethrin sprays. At a 10 per cent concentration in *Deobase* this material caused no knockdown or kill of house flies.

In other tests, given in table 2, space sprays containing allethrin plus DDT and either sulfoxide or piperonyl butoxide gave similar knockdown and kill.

Sulfoxide and piperonyl butoxide were compared as synergists for pyrethrum in two series of tests against free-flying

Table 1.—Effectiveness against house flies of sprays containing either sulfoxide or piperonyl butoxide as synergists for pyrethrum or allethrin. Average of 4 tests.

Material in Deobase (Milligrams per Milliliter)	Per Cent Knockdown in—		Per Cent Kill in 1 Day
	5 Minutes	10 Minutes	
Pyrethrum Sprays			
Pyrethrins 0.2 plus—			
Sulfoxide 2	89	98	85
Piperonyl butoxide 2	78	97	78
Pyrethrins 1 (no synergist)	92	97	37
Allethrin Sprays			
Allethrin 0.2 plus *Butyl Cellosolve* 16 plus—			
Sulfoxide 2	14	56	25
Piperonyl butoxide 2	10	54	34
Pyrethrins 1 (no synergist)	82	90	32

Table 2.—Effectiveness against house flies of *Deobase* sprays containing allethrin, DDT, and either sulfoxide or piperonyl butoxide. Average of 3 tests.

Material in *Deobase* (Per Cent Concentration)	Dosage, Milliliters per 1000 Cubic Feet	Per Cent Knockdown in— 5 Minutes	10 Minutes	Per Cent Kill in 1 Day
Allethrin 0.15 plus DDT 0.95 plus—				
Sulfoxide 0.75 plus *Velsicol AR-50* 1.60	9.26	26	53	76
Piperonyl butoxide 0.75	9.26	33	54	75
Pyrethrins 0.125 (no synergist)	55.56	93	95	23

malaria and northern house mosquitoes. It was necessary to use different concentrations, since the two species of mosquitoes differ considerably in susceptibility (Fales *et al.* 1952). A toxicant-synergist ratio of 1 to 6 was used with the northern house mosquitoes, and a ratio of 1 to 4 with the malaria mosquitoes. The results, given in table 3, show that the mortality of northern house mosquitoes was greater from the piperonyl butoxide formulation, although the sulfoxide also exhibited good synergism. Against malaria mosquitoes the two materials caused about the same degree of synergism. All formulations gave high knockdown of both species.

Table 3.—Effectiveness against adult mosquitoes of pyrethrum sprays containing either sulfoxide or piperonyl butoxide. Insects exposed for 10 minutes to 13.89 ml. of spray per 1000 cubic feet.

Material in *Deobase* (Milligrams per Milliliter)	Per Cent Kill in 1 Day Males	Females
Culex pipiens (5 tests)		
Pyrethrins 0.4 plus—		
Sulfoxide 2.4	93	49
Piperonyl butoxide 2.4	97	66
Pyrethrins (no synergist) 0.4	72	28
.8	93	46
1.6	98	67
Anopheles quadrimaculatus (4 tests)[1]		
Pyrethrins 0.2 plus—		
Sulfoxide 0.8	98	92
Piperonyl butoxide 0.8	100	88
Pyrethrins (no synergist) 0.2	90	72
.6	98	80

[1] 5 per cent of acetone by volume used as a cosolvent in each spray.

Aerosols.—Tests were also made with high-pressure aerosols containing sulfoxide as a synergist for both pyrethrum and allethrin in comparison with piperonyl butoxide. These aerosols contained 0.4 per cent of insecticide, 2 per cent of synergist, 6 per cent of methylated naphthalenes and 85 per cent of *Freon-12*. The pyrethrum aerosols also contained 5 per cent of *Deobase* and the allethrin aerosols 6.6 per cent. As shown in Table 4, the pyrethrum aerosols gave a higher knockdown and kill than the allethrin aerosols. The knockdown and kill of house flies were equal with the two pyrethrum aerosols, but of the two allethrin aerosols the one containing sulfoxide caused slightly less knockdown and kill than the one containing piperonyl butoxide.

Table 4.—Effectiveness against house flies of aerosols containing either sulfoxide or piperonyl butoxide as synergist for pyrethrum or allethrin.

Insecticide and Synergist	Per Cent Knockdown in— 5 Minutes	10 Minutes	15 Minutes	Per Cent Kill in 1 Day
High-pressure aerosols (2.32 grams per 1,000 cubic feet)				
Pyrethrum (4 tests)				
Sulfoxide	53	80	88	88
Piperonyl butoxide	56	82	90	92
Allethrin (6 tests)				
Sulfoxide	14	43	63	50
Piperonyl butoxide	22	45	68	60
Low-pressure aerosols (1.16 grams per 1,000 cubic feet)				
Pyrethrum—DDT (5 tests)				
Sulfoxide	13	42	63	80
Piperonyl butoxide	13	36	54	69

Further tests were made with low-pressure pyrethrum-DDT aerosols, which contained 0.4 per cent of pyrethrins, 2 per cent of DDT, 1 per cent of either sulfoxide or piperonyl butoxide, 5 per cent of methylated naphthalenes, 6.6 per cent of deodorized kerosene, and 85 per cent of a 1:1 mixture of *Freon-11 and 12*. The results are summarized in table 4. The aerosols containing sulfoxide appeared to be better in both 15-minute knockdown and mortality of house flies.

A well-known aerosol used on aircraft contains 1 per cent of pyrethrins, 3 per cent of DDT, 5 per cent of cyclohexanone, 2 per cent of lubricating oil, 4 per cent of deodorized kerosene, and 85 per cent of *Freon-12*. A similar formulation but with sulfoxide or piperonyl butoxide added at 2 per cent and the lubricating oil reduced to 1 per cent and the propellent to 84 per cent was more effective when sulfoxide was used as the synergist. The data are summarized in table 5, series I.

Another aircraft aerosol, containing 1.2 per cent of pyrethrins, 2 per cent of DDT, 8 percent of methylated naphthalenes, 4.8 per cent of deodorized kerosene, and 84 per cent of *Freon-12*, was compared with a similar formulation in which 2 per cent of sulfoxide had been added and the propellent reduced to 82 per cent. As shown in table 5, series II, the addition of the synergist resulted in a marked increase in both knockdown and kill.

Table 5.—Sulfoxide and piperonyl butoxide compared as synergists against house flies in pyrethrum-DDT high-pressure aircraft-type aerosols. 4 tests in series I and 3 in series II.

Synergist	Per Cent Knockdown in— 5 Minutes	10 Minutes	15 Minutes	Per Cent Kill in 1 Day
Series I (0.35 gram per 1,000 cubic feet)				
Sulfoxide	7	37	54	61
Piperonyl butoxide	10	23	32	37
Series I (1.16 grams per 1,000 cubic feet)				
Sulfoxide	55	79	91	97
Piperonyl butoxide	54	81	89	94
Series II (0.37 and 0.38 gram per 1,000 cubic feet)				
Sulfoxide	24	65	82	81
No synergist	9	31	38	50

The first aircraft aerosol, both with and without sulfoxide, was also tested against American cockroaches by the method described by Fales *et al.* (1951). Without the sulfoxide 34 per cent of large nymphs and 54 per cent of adult females were killed within 5 days; with the sulfoxide these kills were increased to 60 and 78 per cent, respectively (average of 6 tests at 20 grams of aerosol per 1,000 cubic feet).

CONCLUSIONS.—These experiments further establish the value of sulfoxide as a synergist for pyrethrum and allethrin, and substantiate the findings of Gersdorff *et al.* (1952) and Mallis *et al.* (1952) that this material ranks with piperonyl butoxide as a synergist. When used with allethrin it was less effective than when used with pyrethrum, which is also in agreement with the findings of Gersdorff and coworkers.

In sprays containing allethrin and DDT, sulfoxide and piperonyl butoxide acted similarly. In aerosols containing pyrethrum and DDT, sulfoxide was the more effective against house flies.

In the sprays sulfoxide was less effective than piperonyl butoxide as a pyrethrum synergist against *Culex* mosquitoes and equal in effectiveness against *Anopheles* mosquitoes.

In aerosols the addition of sulfoxide to a formulation containing pyrethrum and DDT increased its performance against cockroaches.

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Mite Control on Legume Seed Crops[1]

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When it was recognized that the alkali bee, *Nomia melanderi*, was the principal pollinator for alfalfa seed in the Yakima Valley and was responsible for yields in excess of 1000 pounds per acre, large scale alfalfa seed production was undertaken wherever large concentrations of *Nomia* bees could be found. Such high yields could not be obtained without control of insect pests such as lygus bugs. Although control measures for most of these pests had been worked out in other states, the two-spotted spider mite frequently caused serious damage to alfalfa and to clover seed crops. *Tetranychus bimaculatus* Harvey is the common species, although *T. atlanticus* McG. is present in some localities.

Enormous populations of mites frequently develop on alfalfa. Where parts of the field receive inadequate irrigation the mite damage is more evident and the top growth of the plants often is killed. However, there is no evidence that increased populations develop on such plants. On the contrary, preliminary studies indicate greater populations are produced on plants receiving more ample supplies of water. When populations are large, the webbing that the mites spin may completely envelop the plants. At such times large masses of mites may be found clustering at the top of the plants.

Little is known of the effects of low populations of mites on seed production. However, because of the frequent population eruptions which often end in killing the plants, it appears desirable to control mites when a sample of leaves taken at the bud stage of the crop shows about one-fourth of the leaves to be infested with mites.

The selection of an acaricide for legume seed fields poses two problems. The material must be relatively harmless to *Nomia melanderi* and other pollinators if applied during bloom. It must also have long residual effectiveness for economy and to reduce crop damage from application equipment as a result of too frequent application. Preliminary tests with Aramite were made in 1950 (Klostermeyer 1951) and additional materials were tested in 1951 and 1952.

METHODS AND MATERIALS—In 1951, 13 spray and dust treatments were applied to 0.031-acre plots of Kenland red clover in an incomplete block design of four replications (Plan 11.2, Cochran & Cox 1950). Six of the treatments were applied as dusts at about 35 pounds per acre using a tractor-mounted 4-nozzle power duster trailing a canvas drag that covered a 6-foot swath. Three trips through the plots were needed to cover the 18-foot-wide plots. The seven other treatments were applied as sprays at 25 gallons of insecticide mixture per acre with a tractor-mounted sprayer at 75 pounds p.s.i. pressure. Hollow cone nozzles were used, with 18 of them covering the 18-foot-wide swath. All but one of the formulations used were emulsions. The materials and rates of application used of active ingredient per acre were:

3 per cent Aramite dust, 1.8 pounds Aramite per acre.
Aramite emulsion, containing 4.8 pounds Aramite per gallon, 1.8 pounds Aramite per acre.
10 per cent R-242 dust (*p*-chlorophenyl phenyl sulfone), 2.5 pounds R-242 per acre.
50 per cent *Ovotran*, *p*-chlorophenyl *p*-chlorobenzene-sulfonate, wettable powder, 4 pounds *Ovotran* per acre.
50 per cent *Ovotran* emulsion, 2.5 pounds *Ovotran* per acre.
50 per cent compound 923 emulsion (2,4-Dichlorophenyl ester of benzene sulfonic acid), 2.25 pounds compound 923 per acre.
1.5 per cent *DN-4* dust (dinitro-*o*-cyclohexylphenol dicyclohexylamine salt), 0.75 pounds *DN-4* per acre.
1.5 per cent methyl parathion dust, 0.4 pounds methyl parathion per acre.
33.4 per cent Metacide emulsion (a mixture of parathion and methyl parathion), 0.3 pounds per acre.
32.1 per cent demeton (active ingredient of *Systox*) emulsion, 0.6 pounds per acre.
45.7 per cent schradan, 1.1 pounds per acre.
84 per cent sulfur, 30 pounds per acre.

The field was treated for lygus bugs on July 2 with 20 pounds of 10 per cent DDT dust per acre. Acaricides were applied July 18 and again on August 2. The efficacy of the treatments was determined by periodic counts of the mites of 30 leaflets collected at random from each plot. The

[1] Scientific Paper No. 1253, Washington Agricultural Experiment Stations, Pullman. Project 1066.
[2] David R. Malcolm and Adelaide Burgess assisted on the project in 1951 and W. B. Rasmussen assisted in 1952.

leaves were placed in paper bags and held under refrigeration until they could be examined. The mites on the center leaflet of each leaf were counted with the aid of a binocular microscope. The number of mites (n) per 30 leaflets was converted to the logarithm$_{10}$ ($n+1$) for statistical analysis. Records were also kept of predatory mites, and collections were made with an insect net to determine the effects of the materials on other insects in the field.

In 1952, 16 treatment combinations were tested on alfalfa in a balanced lattice factorial design of 5 replications (Plan 10.2, Cochran & Cox 1950). Plots were 0.022 acre in size. Eight acaricides were applied as sprays in combination with 6 pounds of toxaphene per acre. The same acaricides were also put on with 2 pounds of DDT per acre. Each of the treatments was applied in 25 gallons of water at 75 pounds pressure.

The acaricides and rates of application of toxic ingredient per acre were:

36 per cent *DN-289* (dinitro-sec-butylphenol triethanolamine salt), 1 pound per acre.
2 pounds per gallon DMC emulsion (di(*p*-chlorophenyl) methyl carbinol), 2 pounds per acre.
2 pounds per gallon Aramite emulsion, 2 pounds per acre.
2 pounds per gallon *Chlorobenzilate* or *Geigy 338* (2 hydroxy-2, 2-bis (4-chlorophenyl) ethyl acetate), 2 pounds per acre.
42.4 per cent demeton emulsion, 0.25 pounds per acre.
50 per cent *Ovotran* wettable powder, 3 pounds per acre.
4 pounds per gallon parathion emulsion, 0.25 pounds per acre.

A specially designed trailing boom tractor-mounted sprayer was used. The alfalfa was irrigated by shallow ditches at a 3-foot spacing. Five "boomlets" consisting of lengths of pipe hinged to a crossbar mounted on the tractor travelled in the ditches. At the lower end of the boomlets a nozzle sprayed out and up on each side of the boomlet. Two additional nozzles on the upper end of the boomlets sprayed down. Vine spreaders at the lower end of the boomlets spread the plants apart as the boomlets were drawn through the crop thus permitting more thorough application of the spray to the undersides of the leaves.

DDT and toxaphene without acaricides were sprayed on the appropriate plots on June 30 for lygus bug control. Since the mite population developed very slowly, on July 19 potato leaves infested with *Tetranychus bimaculatus* were scattered throughout the field. These provided an initial mite population which became large enough to permit making comparisons among treatments.

The acaricides were applied on August 9 in mixtures with DDT or toxaphene. A second application of *DN-289* and of parathion was made a week later.

Mite counts were made at weekly intervals after spraying. Forty leaves taken at random from each plot were put through a brushing machine (Henderson & McBurnie 1943) that removed the mites and deposited them on a revolving glass plate coated with polyvinyl alcohol-water solution. Cross strips comprising one-tenth of the plate area were examined to determine the mite population. Since the number of mites was relatively low, the $\sqrt{n+0.5}$ was considered to be the appropriate transformation for statistical analysis of the numbers (n) of mites.

1951 RESULTS.—Aramite gave excellent control as a dust and as a spray at 1.8 pounds per acre per application for a period of 5 weeks. The population showed a steady decline until the sixth week, when regrowth of the clover provided abundant untreated surfaces for mite development. The two applications of demeton totaling 1.2 pounds of material per acre gave superior control but also showed an increase in mite population at the end

Table 1.—Effects of acaricides on mite and predator populations on red clover, Prosser, Washington, 1951.

TREATMENT	TOTAL MITES IN 6 COUNTS, ADJUSTED TREATMENT MEAN		TOTAL PREDATORS PER 10 SWEEPS, ADJUSTED TREATMENT MEAN, AUG. 8[1]	
	Log ($n+1$)	Mean No.	Log ($n+1$)	Mean No.
Dusts				
Aramite	2.054	113	1.752	56
Methyl parathion	2.881	760	0.765	6
Ovotran	3.038	1091	1.684	48
R-242	3.081	1205	1.796	62
Sulfur	3.304	2014	1.520	33
D-4	3.325	2113	1.767	58
Sprays				
Demeton	1.669	46	1.404	25
Ovotran wettable	2.317	208	1.592	39
Aramite	2.585	384	1.692	49
Schradan	2.850	707	1.556	36
Ovotran emulsion	2.925	841	1.915	82
Compound 923	3.098	1253	1.605	40
Metacide	3.550	3548	1.297	19
SEx =	0.803		0.121	

[1] Including spiders, Chrysopidae, Nabidae, Anthocoridae, *Geocoris*, and ladybird beetles.

of 6 weeks. *Ovotran* spray at 4 pounds of material for each application resulted in fair mite control, but lower concentrations either as a spray or a dust were not effective. None of the other materials prevented an increase in the mite population (Tables 1 and 2).

There was no clear relation between the predator populations and mites. However, Metacide, methyl parathion, sulfur, and schradan which had high mite populations also had low general insect and predator populations. On the other hand, demeton had a low mite population as well as a low predator population, but Aramite dust had a low mite population with a high predator population (Table 1).

1952 RESULTS.—The statistical analyses indicated significant differences among treatments for each count during the 6 weeks of observation (Table 3). In all cases, plots treated with the DDT combinations had significantly higher mite populations than did those treated with the toxaphene combinations. The *DN-289* treatment resulted in the lowest mite population, but the mixture of this material with the DDT and toxaphene emulsions caused severe leaf burning which may have been partly responsible for the superior control. Aramite again resulted in excellent mite suppression throughout the 6 weeks of observation. Demeton, DMC, and *Chlorobenzilate* gave good control, but populations were showing an increase at the end of 6 weeks. The mites in the *Ovotran* plots declined slowly in numbers but never reached the low levels resulting from the use of the other materials. At the end of 6 weeks, the population in plots treated only with toxaphene was 8 times that of parathion-toxaphene and 46 times that of Aramite-toxaphene. Plots treated only with DDT had 4 times more mites than parathion-DDT and 34 times more than Aramite-DDT. Although a completely untreated check was not included in the experimental design, it is of interest that an adjacent area not treated with insecticides or acaricides had a lower mite population than any of the treatments. It should be noted that the population of mites in these tests was low, and even in plots not treated with an acaricide the damage was probably not of economic importance.

Table 2.—Effects of acaricides on the development of mite populations in red clover, Prosser, Washington, 1951.

TREATMENT	MEAN NUMBER OF MITES PER 30 LEAFLETS				
	July 13[1]	July 20	Aug. 1	Aug. 15	Aug. 29
Dusts					
Aramite	8	10	5	3	36
Methyl parathion	24	50	168	252	1101
Ovotran	51	58	142	405	751
R-242	21	30	120	411	1973
Sulfur	9	17	122	455	1225
D-4	16	56	188	596	1515
Sprays					
Demeton	46	5	7	2	28
Ovotran wettable	11	41	44	25	58
Aramite	10	52	38	15	209
Schradan	33	43	62	254	696
Ovotran emulsion	24	50	169	252	1101
Compound 923	29	47	138	220	1408
Metacide	27	50	152	565	2440

[1] Pretreatment count.

Table 3.—Effects of acaricides on mite populations on alfalfa when used in combination with DDT and toxaphene, Prosser, Washington, 1952.

TREATMENT	NO. MITES PER 20 LEAVES, TREATMENT MEAN				
	Aug. 7[1]	Aug. 14	Aug. 20	Sept. 4	Sept. 18
Acaracide combined with DDT					
None	46	68	76	276	240
Demeton	68	12	4	16	32
Aramite	122	20	4	6	8
Ovotran	132	30	26	20	22
Chlorobenzilate	114	18	8	50	10
DMC	60	24	4	4	34
Parathion	84	24	8	32	66
DN-289	94	28	2	2	2
Mean	90	28	16	51	52
Acaracide combined with toxaphene					
None	22	20	36	80	138
Demeton	16	12	2	6	6
Aramite	34	28	4	4	2
Ovotran	34	10	4	12	8
Chlorobenzilate	12	6	2	8	4
DMC	18	8	2	4	12
Parathion	18	2	2	10	18
DN-289	26	0	2	6	2
Mean	22	43	27	64	95
Untreated	19	5	5	11	12

[1] Prior to treatment with acaricide but following treatment with DDT and toxaphene.

EFFECTS OF ACARICIDES ON PREDATORS.—In supplemental sweep net collections made in 1952, it was found that 1 week after application of the acaricide-insecticide combination the population of anthocorid bugs was reduced in the toxaphene treatments and severely reduced in the DDT-parathion combination (Table 5). The spider population was reduced by parathion. The population of lady beetles was closely associated with the numbers of pea aphids, and both were fewer in number in the toxaphene plots.

In collections made 1 month after application, the anthocorids were still fewer in number in the toxaphene plots. Although this may be related to the insecticide, it probably also reflects the differences in mite populations since the

Table 4.—Statistical summary of the effects of acaricide-insecticide combinations on mite populations in alfalfa, Prosser, Washington, 1952.

ACARICIDE	ADJUSTED MEANS, $\sqrt{n+0.5}$ OF THE TOTAL MITES IN SIX COUNTS AFTER TREATMENT		
	Combined with DDT	Toxaphene	Mean
None	33.62	21.47	27.55
DN-289	6.73	5.09	5.91
DMC	8.55	6.47	7.52
Aramite	7.89	7.18	7.53
Chlorobenzilate	10.38	6.29	8.33
Demeton	11.73	7.05	9.39
Ovotran	13.77	8.20	10.98
Parathion	14.77	8.85	13.00
Mean	19.93	8.82	

Standard error of mean:
for treatments = 1.028
for acaricides averaged over DDT and toxaphene = 0.726
for DDT and toxaphene averaged over acaricides = 0.364

anthocorid population was also low in the untreated area which had few mites but many aphids. The population of predaceous mites was too low to permit interpretation.

DISCUSSION.—In the 3 years of testing, Aramite, either as a dust or spray has resulted in consistently good mite control. This material has been used by farmers for 2 years with a variety of application methods, including aerial spraying and dusting, and has given good results. Furthermore it is relatively non-toxic to pollinators and to predators. Demeton appears to be satisfactory for mite and aphid control, but dosages above 0.25 pound per acre or repeated applications appear necessary for adequate residual effects. Demeton resulted in control superior to that of schradan, even when used at one-third the dosage of schradan. *Ovotran* was effective at 4 pounds per acre but not at 2.5 pounds or 3 pounds. *DN-289* spray gave excellent control, but because of the foliage burning resulting from the mixture with emulsifiable materials, it is not known whether the control was due to the direct effects of the material or to the temporary destruction of the leaves. *Chlorobenzilate* and DMC show promise in one year of testing at rates of application comparable to Aramite. No adverse effects were noted from the use of these compounds.

Parathion and methyl parathion caused a reduction in the population but failed to prevent a rapid increase in the population after 2 weeks. In addition these materials are reported to be toxic to

Table 5.—Effect of acaricide-insecticide combinations on insect populations in alfalfa, Prosser, Washington, August 19, 1952.

ACARICIDE	INSECTS PER 100 SWEEPS, TREATMENT TOTALS					
	Anthocorids	Pea Aphids	Lady Beetles	Lacewings	Spiders	Thrips
			With DDT			
None	102	1096	26	28	17	1517
DN-289	80	434	12	10	23	512
DMC	81	656	20	14	10	832
Aramite	81	1549	36	11	22	1354
Chlorobenzilate	123	911	27	15	36	1394
Demeton	96	87	0	17	15	1321
Ovotran	90	1029	29	22	33	1297
Parathion	15	27	5	9	7	395
Mean	84	724	19	16	20	1078
			With Toxaphene			
None	13	392	9	19	4	1801
DN-289	21	161	0	8	4	462
DMC	25	202	0	20	4	1021
Aramite	53	456	0	10	19	1600
Chlorobenzilate	27	325	0	18	7	1433
Demeton	33	85	6	12	9	978
Ovotran	47	411	0	12	17	1862
Parathion	32	107	0	7	6	494
Mean	31	267	2	13	9	1206

pollinating insects, thus limiting their use to pre-bloom applications. These materials also cause severe reduction in predator populations which may contribute to the rapid increase in mite populations following application of such treatments.

DDT treatments at 2 pounds per acre resulted in greater mite populations than toxaphene treatments at 6 pounds per acre, whether the materials were used alone or in combination with acaricides. At such a large dosage of toxaphene it is possible that some acaricidal action occurred. However, the fact that soil applications of DDT increase mite populations (Klostermeyer 1953) indicates that some other factor may be involved. It is possible that DDT affects the mites or the physiology of the plants in some way as to promote an increase in population.

Forage legumes, whether raised for hay or for seed, harbor a large number of species of insects and related forms of life. The ecological relationships of these organisms are extremely complex. It is evident from these data that some insecticides and acaricides have a greater range of effects than others. Certain materials, such as Aramite, affect scarcely anything but plant feeding mites, whereas others, such as parathion, cause population reductions in nearly every species. As was indicated by the decline in numbers of lady beetles and pea aphids with some materials, the reduction in predator populations may result from two causes—one a direct effect of the insecticide on the predator, and the other an indirect effect resulting from a reduction in the food supply of the predator. Those materials which reduce the number of plant feeding species without harming predators may bring about a considerable reduction in predator numbers simply by reducing their food supplies. It is difficult to determine which factor may be involved with any particular material.

SUMMARY.—Aramite, as a spray or dust at 2 pounds per acre, has provided the most effective control for the two-spotted mite on legume seed crops with the least deleterious effect on pollinating insects and predators. Other effective materials include demeton, DMC, *Chlorobenzilate*, Ovotran and *DN-289*. However, problems of residues, costs, and application limit the use of these materials. Acaricides which were not effective include methyl parathion and parathion, compound 923, schradan, and sulfur. A greater population of mites developed where acaricides were used in combination with DDT than when used in combination with toxaphene.

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ERRATA

Authors have requested the following corrections:

Vol. 46, No. 6, page 1089, column 1, line 68: Change 55 mm. to 75 mm.

Vol. 44, No. 4, page 622, column 1: Under G-651 delete the 2 opposite cyclohexanone.

Effects on Some Insects of the Blood and Manure of Cattle Fed Certain Chlorinated Hydrocarbon Insecticides

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The control of external bloodsucking parasites by internal treatment of the host has been demonstrated by a number of workers. Knipling (1938) showed that larvae of the horn fly, *Siphona irritans* (L.), could not develop in the manure of cattle fed phenothiazine. The manure of cattle fed zinc oxide was also shown to be toxic to larvae of the horn fly by Bruce (1942).

Lindquist *et al.* (1944) showed that the blood of rabbits given oral doses of pyrethrum and DDT was lethal to bed bugs, *Cimex lectularius* (L.) and *hempiterus* (F.), and also to stable flies, *Stomoxys calcitrans* (L.). However, high mortality of the insects was caused in some of their tests, whereas in other little or no mortality resulted. Several species of bloodsucking arthropods allowed to feed on a rabbit given BHC either died or were affected in tests made by De Meillen (1946).

Knipling *et al.* (1948) tested a number of insecticides and drugs as chemotherapeutic agents against the body louse, *Pediculus humanus humanus* L., the yellow-fever mosquito, *Aedes aegypti* (L.), the lone star tick, *Amblyomma americanum* (L.), and the ear mite, *Psoroptes equi cuniculi* (Del.). The arthropods were allowed to engorge on rabbits given various amounts of the different chemicals. The results of tests with 2-pivalyl-1,3-indandione and with BHC demonstrated the possibility of controlling external bloodsucking parasites through internal medication of their hosts.

During the last few years the Bureau of Animal Industry and the Bureau of Entomology and Plant Quarantine at the Kerrville, Texas, station have been investigating the toxicity of insecticides to livestock. During 1950 and 1951 this work afforded the authors an opportunity to study the effects on some insects feeding on the blood or in the manure of cattle on a ration containing various chlorinated hydrocarbon insecticides. The observations made are herein reported.

MATERIALS AND METHODS.—The animals used in the studies were high-grade Hereford cattle of yearling age. The insecticide was added to the animals' feed in acetone solution. With lindane, for instance, 1 p.p.m. was obtained by adding 1 cc. of a lindane solution containing 0.454 mg./cc. to 1 pound of feed. Ten and 100 p.p.m. were obtained by adding 4.54 mg./cc. and 45.4 mg./cc., respectively. Details of the feeding are described by Radeleff (1951). The addition of other insecticides to the feed was handled in a similar manner. Besides lindane, observations were made on the effect of BHC (12 per cent gamma), dieldrin, aldrin, chlordane, and toxaphene. Each insecticide was fed to two animals.

The bloodsucking insects included in the observations were horn flies, stable flies, and mosquitoes. Observations were also made on the effect of the blood and/or feces of the insecticide-fed animals on house flies, *Musca domestica* (L.), common cattle grubs, *Hypoderma lineatum* (De Vill.), secondary screw-worms, *Callitroga macellaria* (F.), and screw-worms, *Callitroga hominivorax* (Coquerel).

The horn flies and stable flies were liberated in a large screened cage or stall containing the animal. The horn flies were allowed to remain on the animal, but the stable flies were removed after engorgement and placed in clean cages in the laboratory. The stable flies were also fed in the laboratory on blood (citrated) drawn from the animals. The mosquitoes were allowed to feed on the animals either through a cloth netting or in direct contact with the skin.

The effects of the manure on the development of the larvae of some of the insects were also studied. The manure was usually collected in a glass jar or clean shovel as it dropped from the animal so as to prevent contact with the ground. If the manure did fall on the ground, only the top surface was removed for testing. After collection, it was placed in glass jars over moistened sand and infested with eggs or newly hatched larvae of the test insect. The toxicity of the manure to the insects was studied after their emergence and

also after they had been confined in glass jars containing freshly collected manure from the treated animals.

TESTS WITH LINDANE.—*Horn flies.*—The first test on adult horn flies was made after the two experimental animals had been on a diet containing 100 p.p.m. of lindane for 80 days. An estimated 50 to 100 flies were released on each animal held in a screened stall. On both animals the flies were either knocked down or killed within 5 hours; there was a negligible reduction in numbers of flies released on the control or untreated animal. The test was repeated 3 days later—next to the last day that the animals were on the lindane diet. The horn flies were again eliminated from the animals within 5 hours.

The blood of two animals given 10 p.p.m. of lindane after 83 and 84 days showed no appreciable toxicity to the flies. On the day after the lindane feeding was terminated, one of the animals fed lindane at 100 p.p.m. was still very toxic to the flies. No flies were on the animal 5 hours after they were released. On the 7th day after lindane was omitted from its feed there was 88-per cent reduction of flies in 5 hours and 100 per cent in 24 hours. Similar results were obtained 10 and 14 days after the lindane feeding was stopped. After 21 days 75 horn flies were released on one of the animals fed 100 p.p.m. of lindane. There was very little reduction of flies in 5 hours, but 65 per cent were killed in 18 hours and 100 per cent after 24 hours. Further observations were not possible owing to the onset of cold weather. The last test indicated, however, that the animal was losing its toxicity to the flies.

Observations were also made on the effect of toxicity of the manure on larvae of the horn fly. Eggs were obtained from the flies by confining them over manure placed in glass jars containing moistened sand. The manure was from animals that had received 10 and 100 p.p.m. of lindane for 84 days. The manure from one of the animals that had received 100 p.p.m. of lindane greatly retarded the growth of the larvae and only a few adults emerged. Similar results were obtained 6 days after lindane was omitted from the diet. However, 17 days after the lindane feeding was stopped, the manure appeared to be nontoxic to the larvae. The manure from the animals fed 10 p.p.m. of lindane was not toxic to the larvae.

Stable flies.—Stable flies from the laboratory colony were allowed to feed on animals receiving 10 and 100 p.p.m. of lindane. After the flies engorged, they were held at 80° F. for 24-hour mortality records. Three tests with a minimum of 20 flies per test were made on the 83rd and 84th day of lindane feeding. The mean mortalities recorded for flies feeding on the animals given 10 and 100 p.p.m. were 38 and 82 per cent, respectively, and for the control animal 20 per cent. Flies allowed to engorge on an animal given 100 p.p.m. 6 days after the feeding was stopped appeared unaffected after 24 hours.

The blood of the treated animals was further tested for toxicity by making it continuously available to the flies held in small wire cages. Eighty flies were allowed to feed for 48 hours on venous blood drawn on the 59th day of feeding from an animal receiving 100 p.p.m. of lindane. A mortality of 78 per cent resulted, and there was 15 per cent mortality of flies similarly fed on blood taken from a control animal. After 75 days of lindane feeding, blood from the animal was made available to 120 flies for 48 hours. Mortality of the flies was 41 per cent, compared with 15 per cent for the control.

Stable flies were also exposed to hair clipped from the neck of the animal that had received 100 p.p.m. of lindane for 84 days. This was accomplished by placing the flies in petri dishes containing the hair. No mortality was evident after 24 hours.

Mosquitoes.—Yellow-fever mosquitoes, were allowed to engorge on an animal receiving 100 p.p.m. of lindane. In three tests made during the 48th to 63rd day of lindane feeding from 50 to 90 per cent of the mosquitoes were dead after 24 hours. However, in another test no mortality was noted with 50 mosquitoes allowed to engorge on the same animal after 70 days of lindane feeding.

Screw-worms.—Newly hatched larvae of screw-worms, were placed in a medium composed of equal parts of blood and ground beef. The blood was taken from an animal that had received 100 p.p.m. of lindane for 84 days. The larvae developed and pupated and the emerging flies appeared normal.

House flies.—Several tests were made on the toxicity of the manure to house fly larvae. The manure of an animal fed 10 p.p.m. of lindane was not toxic to the larvae even after 84 days of feeding. Manure taken at the same time from an animal fed 100 p.p.m. greatly retarded but failed to prevent the development of larvae and emergence of adult flies. No tests were made after the insecticide was omitted from the diet of the animal.

Adult house flies and also adult secondary screw-worms confined for 5 hours over fresh manure from an animal fed the 100 p.p.m. of lindane for 84 days showed no mortality during a subsequent 24-hour observation period.

Cattle grubs.—Two common cattle grubs, apparently normal, appeared in the back of an animal after 84 days of lindane feeding at 100 p.p.m.

TESTS WITH BHC (12 PER CENT GAMMA).—*House flies.*—House flies were reared on manure collected from two animals that had received a ration containing 100 p.p.m. of the insecticide. The animals were given the contaminated feed twice daily for 112 days. Details of the feeding are described by Claborn *et al.* (1953). The manure was collected and infested with eggs of the house fly 2 days after feeding of the insecticide was stopped. The manure caused no apparent mortality to the developing larvae or to the adults.

TESTS WITH DIELDRIN AND ALDRIN.—*Horn flies.*—The toxicity of the manure of cattle fed 25 p.p.m. of dieldrin or aldrin in the diet as described by Claborn *et al.*[1] to larvae and adults of the horn fly was determined in tests similar to those described for lindane. The manure was first tested 43 days after the feeding started. The larvae showed no signs of developing after hatching. Feeding of the insecticides was discontinued after 56 days. Tests made on the 55th day of feeding and again 47 days after feeding ceased showed the manure of the dieldrin- and aldrin-treated animals to be completely lethal to horn fly larvae.

Stable flies.—The toxicity of the manure of these animals was also tested against stable fly larvae. The tests were made 71 days after the 56-day feeding at 25 p.p.m. was terminated. The larvae appeared to develop and pupate normally. However, shortly after emergence the flies exhibited typical insecticide poisoning and all died within a few hours. No further observations were made.

House flies.—An attempt was made to rear house fly larvae on the manure of the animals that had been fed dieldrin and aldrin (25 p.p.m.) for 43 days. Most of the larvae appeared to be affected throughout their growth and formed only a few very small pupae. One abnormal fly emerged from the manure of an animal fed dieldrin, but none from that of the animals fed aldrin. The test was repeated after the animals had been on the diet for 51 days. Development of the larvae appeared normal, but most of the pupae were slightly smaller than those formed in the manure of the control animal. No flies emerged. The insecticides were omitted from the diet after the 56th day. Six days after feeding of the insecticide was discountinued, the manure was again tested. The results were similar to those obtained on the 51st day, except that two flies emerged from the manure of one of the dieldrin-treated animals but none from that of the animals fed aldrin. Tests were also made 32 and 71 days after the feeding of the insecticides was terminated. In both tests the larvae developed normally and adults emerged from the pupae. However the flies died within a few hours after emergence. In the various obsevations the results with dieldrin and aldrin were similar.

Cattle grubs.—Dieldrin and aldrin fed at 25 p.p.m. showed little apparent toxicity to the common cattle grub. After 55 days of insecticide feeding, 14 and 11 grubs (all three instars) were noted in the backs of the animals fed dieldrin and aldrin, respectively. No dead grubs were observed.

TESTS WITH CHLORDANE.—*Horn flies and house flies.*—Chlordane was included in the tests described with dieldrin and aldrin, and the same dosage and procedure were used. The manure was tested against horn fly larvae after 43 and 55 days, and against house fly larvae after 43 and 51 days. The manure from an animal fed chlordane showed no apparent toxicity to larvae of either species.

Cattle grubs.—Fifteen apparently normal cattle grubs were noted in the back of an animal after 55 days of chlordane feeding.

[1] Unpublished manuscript.

TESTS WITH TOXAPHENE.—The manure of two animals fed 100 p.p.m. of toxaphene for 112 days as described by Claborn *et al.* (1953) was tested only against house flies. Two days after the feeding was terminated, samples of the manure were collected from each animal and infested with house fly eggs. The manure showed no toxicity to either the developing larvae or to the adult flies.

SUMMARY.—A study was undertaken at Kerrville, Texas, during 1950 and 1951 of the effects on some insects feeding on the blood or in the manure of treated animals. Hereford cattle were fed for different periods a diet containing the following levels of various chlorinated hydrocarbon insecticides: Lindane at 10 and 100 p.p.m. for 84 days; dieldrin, aldrin, and chlordane at 25 p.p.m. for 56 days; and toxaphene and BHC (12 per cent gamma) at 100 p.p.m. for 112 days. Observations were made on the effects on horn flies *Siphona irritans* (L.); yellow-fever mosquitoes, *Aedes aegypti* (L.); stable flies, *Stomoxys calcitrans* (L.); common cattle grubs, *Hypoderma lineatum* (De Vill.); house flies, *Musca domestica* L.; secondary screw-worms, *Callitroga macellaria* (F.); and screw-worms, *Callitroga hominivorax* (Coquerel). Bloodsucking adults were allowed to feed on the treated cattle. House fly, horn fly, and stable fly larvae were reared on manure from the host animals.

Lindane at 100 p.p.m. was particularly effective against horn flies, the treatment being lethal to flies feeding on a treated animal during the insecticide administration and for at least 21 days thereafter. At 10 p.p.m. lindane appeared ineffective, as was the BHC treatment with house flies. There was some evidence of toxicity to stable flies and mosquitoes that fed on an animal that received 100 p.p.m. of lindane. Its manure was also toxic to horn fly larvae. Manure from cattle fed dieldrin or aldrin was toxic to larvae of horn flies, house flies, and stable flies. The manure from an animal fed chlordane showed no apparent toxicity to either horn fly or house fly larvae. Similar results were obtained with toxaphene against house fly larvae.

Cattle grubs encysted normally in the backs of animals fed lindane, dieldrin, aldrin, or chlordane. There appeared to be no adverse effect on the larvae.

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An Evaluation of Some Natural Enemies of the Olive Scale

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A sustained effort directed toward achieving biological control of olive scale, *Parlatoria oleae* (Colvée), was begun in California in 1951. By that time this scale had spread from a small localized infestation discovered in 1934 at Fresno in the central part of the state to infestations extending from San Diego County in the south to Glenn County in the northern Sacramento Valley. It was also recognized as a major agricultural pest for it was found to attack 211 different species, including in its preferred list such important crops as almonds, apricots, apples, olives, peaches, pears, and plums (McKenzie 1952).

In 1951 A. M. Boyce began a search for this diaspine scale and its natural enemies throughout an extensive area of the world including the region to which it is supposedly indigenous. Between May and November of 1951 he sent to California 63 separate lots of host material from collections made in India, Pakistan, Afghanistan, Iran, Iraq, Syria, Egypt, Lebanon, Cyprus, Israel, Greece, and Spain.[1]

The entomophagous species emerging from the imported host material were tested in quarantine in accordance with the procedure that is standard in biological control work. Only those species that exhibited the habits of primary parasites or were found to be obligatorily predaceous as a result of these tests were released from quarantine for insectary propagation. Emergence in quarantine does not necessarily mean that the species is destined to be of usefulness as a control for *Parlatoria*. For instance, the field-collected *Parlatoria* often has mixed with it one or more species of other diaspine scales. These species may yield their own complement of natural enemies which produce no progeny when tested on *P. oleae*. Intermingled with the *Parlatoria* infesting the bark of deciduous fruit trees in Baluchistan, for example, were individuals of a species of *Diaspidiotus* and also specimens of the Hall scale, *Nilotaspis halli* (Green). The *Diaspidiotus* produced a new species of *Habrolepis* and the Hall scale was parasitized by an undetermined and perhaps new genus of Aphelinidae. None of these parasites could be induced to attack *Parlatoria* in the quarantine laboratory.

The shipments also produced parasites belonging to the genera *Ablerus*, *Azotus*, and *Thysanus*. None of these could be reared successfully as primary parasites and they are presumed to be secondaries as many related species are known to be hyperparasitic. Other aphelinids, such as *Prospaltella*, appeared occasionally in the shipments but attempts to culture them in California were unsuccessful. The reason for this failure has not been determined, however the culture of related forms is often made difficult by a complicated life history which requires the male sex to develop as an obligatory hyperparasite. The entomophagous species which did pass the rigid tests in quarantine are listed in table 1.

Aphytis spp.—Based upon the examination of the imported host material and the emergence of adult parasites it is apparent that the dominant parasitic enemies of *Parlatoria oleae* in its native range are species of the aphelinid genus *Aphytis*. Fortunately, the procedure adopted at the outset of this project was to treat the parasites emerging from *Parlatoria* as distinct biological entities even though morphologically indistinguishable from species extant in California. Material of similar appearance but from different geographic areas was also cultured separately until preliminary observations of a comparative nature had been completed. This policy led to the discovery of certain *Aphytis* which morphologically resemble the species *maculicornis* (Masi) but which are distinctly different biologically. These biological forms are believed to be cryptic or sibling species which collectively form a complex recognized morphologically as *A. maculicornis*. An intensive study of their bio-

[1] Through arrangements made by Dr. Boyce, periodic shipments continued during 1952 and into 1953 from entomologists in India and Pakistan. These were made by Dr. A. P. Kapur of the Indian Lac Research Institute and by Mr. Ahmad Saied Khan, Department of Plant Protection, Government of Pakistan. Two additional shipments were received from Mohd. Rashid Kahn, Entomologist in Charge Codling Moth Scheme, Parachinar, Pakistan. The efforts of these men are gratefully acknowledged.

Table 1.—Imported natural enemies of Parlatoria oleae (Colvée).

SPECIES	DESIGNATION	BIOLOGY	HOST	ORIGIN
Aphytis maculicornis (Masi)	"Indian *Aphytis*"	External, bisexual parasite	*Parlatoria oleae*	India, Pakistan, Afghanistan
Aphytis maculicornis (Masi)	"Persian *Aphytis*"	External, bisexual parasite	*Parlatoria oleae*	Iran, Iraq
Aphytis maculicornis (Masi)	"Spanish *Aphytis*"	External, unisexual parasite	*Parlatoria oleae*	Spain
Aphytis nr. *proclia* (Walker)	"Egyptian *Aphytis*"	External, unisexual parasite	*Parlatoreopsis* sp.	Egypt
Aspidiotiphagus nr. *citrinus* (Craw)	—	Internal, unisexual parasite	*Parlatoria oleae*	Iran
Cybocephalus sp.	—	Predator	*Parlatoria oleae*	Spain
Chilocorus bipustulatus (Linn.)	—	Predator	*Parlatoria oleae*	Israel

logical characteristics has been made by Hafez & Doutt (1954). These sibling species present a difficult problem of nomenclature, and the most practical temporary solution has been to designate them with a common name based on the country where they were first collected. In line with this policy these biological forms are recognized as the Indian *Aphytis*, the Persian *Aphytis*, and the Spanish *Aphytis*. Hafez & Doutt (1954) include a fourth type, the Californian *Aphytis*, in this *maculicornis* complex. The latter form was present in California before this project began, but is distinctly different biologically from any of the imported *Aphytis*.

A form of *Aphytis proclia* (Walker) was reared from *Parlatoreopsis* sp. collected by Boyce in Egypt. This parasite attacks *Parlatoria oleae*, but is exhibits host preferences unlike the members of the *Aphytis maculicornis* complex, and has not proven to be of any consequence in field trials.

Shipments from Iran produced a species of *Aspidiotiphagus* resembling *citrinus* (Craw). This internal parasite of the young olive scale was released in enormous numbers, but recoveries have been made in urban areas only. Its preferred habitat may be such that suitable niches do not exist for this species in commercial orchards. Further evidence suggesting this is to be found in the fact that the original Iranian specimens were from scale infesting *Gleditsia* and *Syringa* and the species was never seen in shipments of plant material taken from olive or deciduous fruit trees. Samples taken from dooryard plantings in California have indicated as high as 45 per cent of the young scale succumbing to the attack of this *Aspidiotiphagus*, but it does not offer much promise of being of value in commercial orchards.

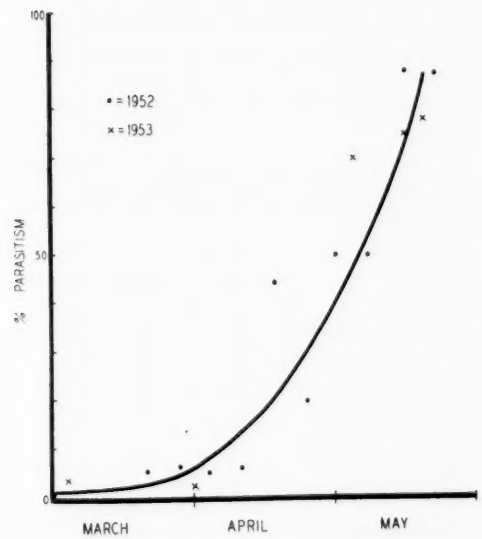
Predators.—The predaceous coccinellid, *Chilocorus bipustulatus* (Linn.), was received from Israel, although a prior shipment from Pakistan contained specimens which died in transit. This species was liberated in the spring of 1952 and was first recovered that fall. This predator has continued to reproduce in the olive orchards although its numbers have not become abundant even in heavy host populations. Its action will probably supplement that of the indigenous *C. stigma* Say which is a commonly encountered but usually ineffective enemy of *P. oleae*.

The tiny nitidulid, *Cybocephalus* sp., has not been recovered from the field. Assumptions based on laboratory observations discourage optimism in regard to the effectiveness of this species.

Persian Aphytis.—The most promising natural enemy imported for the biological control of *Parlatoria* is the Persian *Aphytis*. Its aggressiveness was apparent in the early laboratory cultures, and in the field it has tended to overshadow the other members of its complex as well as the *A. proclia* from Egypt. The progress of this Persian *Aphytis* has been followed in three separate olive orchards and a very marked reduction of the olive scale has occurred in each plot.

In order to evaluate the effectiveness of this parasite it has been necessary to measure both the host population and the mortality caused by the parasites over a period of time. The olive scale in Cali-

fornia has two generations each year. In early spring the scale population in olive orchards is very evenly brooded for it consists almost entirely of maturing females which have spent the winter on the twigs, leaves, and branches of the trees. The majority of these females produce eggs in April and May and the progeny reach maturity in late July and early August. A count of the mature females was used as a measure of the host population, and this was made twice each year to correspond with the peak of development of the females in each generation. The over-wintering generation was counted in late February or early March and the summer generation was sampled in late July. The sampling method adopted in this work was to cut five twigs at random at shoulder height around the periphery of each of five trees. Each twig, however, had to bear at least 10 leaf pairs. These 20 terminal leaves and the twig length bearing them constituted the actual sampling units. These units were selected for they included the current season's growth as well as the older growth and therefore were felt to be representative of the dynamic aspects of plant growth and the attendant scale infestation. The total sample in each plot consisted of 25 twigs bearing 500 leaves. Absolute counts of all live settled stages were made on these leaves and twigs by careful microscopic examination.



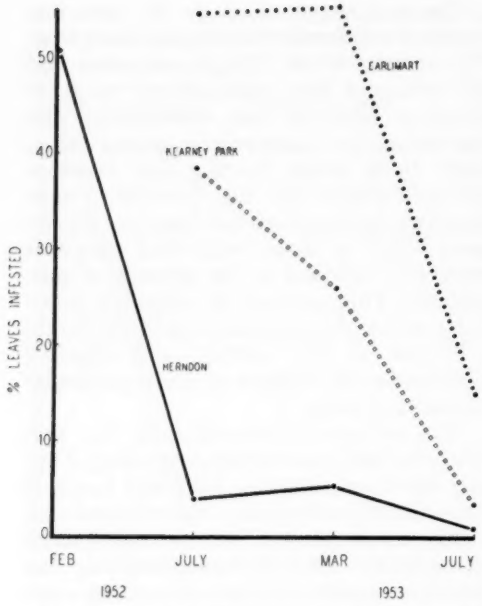
GRAPH 1.—Pattern of parasitism by Persian *Aphytis* 1952–1953.

The mortality caused by the parasites required a different technique of sampling. The activity of the *Aphytis* was measured by cutting a few scale-infested twigs at frequent intervals and determining the parasitism by microscopic examination. Only those scales bearing live developmental stages of the parasites were counted. Scales which had been previously parasitized or those with dead parasites were not included in the records of parasitism. This method of sampling made each count of parasitism a fairly accurate reflection of the existing and effective population of *Aphytis* at that particular moment of time.

The pattern of parasitism by the Persian *Aphytis* was rather surprising. During April and May in 1952 and again in 1953 the parasitism rose sharply and suddenly in an almost exponential fashion (Graph 1). This increase probably has multiple causes but an important combination of contributing factors is the short developmental period of the *Aphytis* under normal field conditions in April and May coupled with the presence of a host population consisting almost entirely of mature females, the preferred host stage.

Because of the spring increase there are enormous numbers of parasites present on the trees during May. However, owing to its evenly brooded condition, the scale population which survives attack suddenly changes from mature females susceptible to parasitization to a population of eggs and crawlers immune to attack by *Aphytis*. The parasites are thus suddenly confronted with virtually a host free period, and their numbers as a consequence are sharply reduced. As the male *Parlatoria* develop they serve as hosts for some of the parasites, but they are not sufficiently satisfactory hosts to maintain a substantial reservoir of *Aphytis*. The parasitism of the females maturing in the summer generation is thus quite low, and parasitism apparently does not increase to any marked extent during the fall months, although occasional samples in October have shown 18 to 20 per cent of the females to be killed by these external parasites. This low parasitism holds through the winter and then undergoes the rapid increase described above during the spring months.

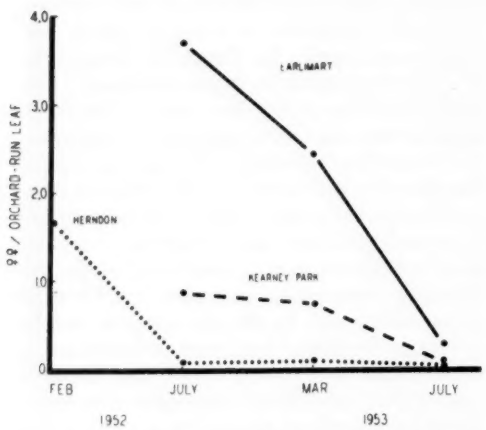
Although this seasonal activity of



GRAPH 2.—Leaf infestation by *Parlatoria oleae* in test plots of Persian *Aphytis*.

Aphytis is intense in the spring of the year and relatively quiet for the remaining 9 or 10 months, it is nevertheless sufficiently effective to cause a marked reduction in the host population (Graph 4). This drop has occurred in each of the three orchards where quantitative data have been obtained (Tables 2, 3, 4), and a detailed examination of these plots seems justified.

Herndon plot.—This was the first plot established and has been under surveillance for 17 months. A sample of the scale



GRAPH 3.—Trend in population density of *Parlatoria oleae* in test plots of Persian *Aphytis*.

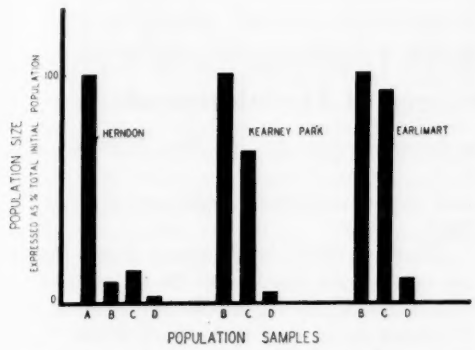
Table 2.—Population samples of *Parlatoria oleae*, Herndon, Fresno County, Calif.

	1952		1953	
	Feb. 28	July 24	March 2	July 28
Total females on twigs	291	19	45	7
Total females on leaves	833	30	36	9
Total females in sample	1124	49	81	16
Leaves infested	255	20	27	9
Leaves infested (%)	51.0	4.0	5.4	1.8
Twigs infested (%)	96.0	40.0	48.0	16.0
Max. female per twig	88	7	25	4
Max. females per leaf	22	8	4	1
Females per infested leaf	3.25	1.5	1.33	1.0
Females per orchard-run leaf	1.66	0.06	0.072	0.018

infestation was taken on Feb. 28, 1952, and releases of the Persian *Aphytis* were made immediately thereafter. These parasite releases were made periodically until May 7, 1952, and none have been made since that date. The parasites established themselves in the plot, followed the pattern of parasitism throughout the seasons as described above and succeeded in reducing the scale population to a remarkable extent. For example, the total number of live mature *Parlatoria* in the samples at the start of this experiment was 1124, and this population was so reduced by parasitism that an equivalent sample taken 17 months later contained only 16 live females. Data taken from this plot are compiled in table 2 and indicate that if the trend continues the pest population will be so reduced that commercial control will be realized within the next season. Although no data have yet been obtained on the percentage of infested fruit it is assumed that the infestation of the leaves can be used as a fairly reliable in-

Table 3.—Population samples of *Parlatoria oleae*, Kearny Park, Fresno County, Calif.

	July 24, 1952	1953	
		March 3	July 28
Total females on twigs	264	112	10
Total females on leaves	440	355	19
Total females in sample	704	467	29
Leaves infested	192	130	17
Leaves infested (%)	38.4	26.0	3.4
Twigs infested (%)	96.0	76.0	24.0
Max. female per twig	35	26	3
Max. females per leaf	18	15	2
Females per infested leaf	2.29	2.73	1.11
Females per orchard-run leaf	0.88	0.71	0.038



GRAPH 4.—Proportional reduction of *Parlatoria oleae* in three test plots of Persian *Aphytis*.
Sample A—Feb. 28, 1952
Sample B—July 24, 1952
Sample C—March 3, 1953
Sample D—July 28, 1953

dex. Graph 2 depicts the trend in infested leaves in the three test plots.

Kearney Park plot.—This plot was established in July 1952 and received periodic colonizations of Persian *Aphytis* until November 11, 1952. Although these parasites were released over a rather long period, the parasitism did not become very high until the spring of 1953 in accordance with the seasonal pattern described before. However, within 1 year from the establishment of the plot the parasites were able to reduce the scale population by 95.9 per cent (Graph 4). Data from this plot are given in table 3.

Earlimart plot.—This infestation was initially the highest of the three plots and parasites were liberated here for only a short period in the summer of 1952. The scales were very heavily encrusted on the leaves and twigs and many of the young scale developed beneath the layer of dead scale coverings of earlier generations. It was felt that this protection plus the presence of considerable dust on the trees in this particular orchard would deter the activities of the parasites. In spite of these unfavorable conditions the parasites have reduced the scale population 90 per cent within 1 year (Table 4), and in view of the experience in the older plot at Herndon (Table 2), this trend is expected to continue.

Although ecologists generally recognize that heavy populations of most organisms suffer mortality from overcrowding it appears in the case of *Parlatoria oleae* that, up to a certain point at least, a high density of the scale may operate to increase the probability of survival of the crawlers. In examining infested leaves it is common to find that the only live scales are those which have developed beneath the dead scale coverings of the parental or earlier generations. The reduction in the host's population density by the parasites may eventually reduce the number of these refuges or protective niches afforded the young scales, and thus will expose them to greater mortality. Graph 3 depicts the reduction in population density of *P. oleae* in the test plots based on number of scale per orchard-run leaf.

Table 4.—Population samples of *Parlatoria oleae*, Earlimart, Tulare County, Calif.

	JULY 24, 1952	1953	
		March 3	July 28
Total females on twigs	103	572	67
Total females on leaves	1837	1216	129
Total females in sample	1940	1788	196
Leaves infested	275	281	75
Leaves infested (%)	55.0	56.2	15
Twigs infested (%)	88.0	96.0	76
Max. females per twig	14	76	7
Max. females per leaf	54	37	5
Females per infested leaf	6.6	4.3	1.72
Females per orchard-run leaf	3.7	2.43	0.258

SUMMARY.—Seven exotic species of entomophagous insects have been imported into California for control of the olive scale. The most effective natural enemies so far established are sibling species belonging to the *Aphytis maculicornis* complex. One of these forms, designated as the Persian *Aphytis*, has greatly reduced the scale population in in several test plots. In view of the annual cost sustained by the olive industry alone in combatting *Parlatoria*, the importation of this Persian *Aphytis* is a contribution of considerable value to agriculture.

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Effect of Curly Top-Infective Beet Leafhoppers on Cantaloup Plants in Varying Stages of Development

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Curly top, a virus disease tramsmitted by the beet leafhopper, *Circulifer tenellus* (Baker), has long been a problem on sugar beets, certain vegetable crops, and ornamentals west of the Rocky Mountains. The symptoms and severity of the disease vary with different plants. Some crops, such as susceptible varieties of sugar beets, garden beets, spinach, and beans show very definite and easily recognized symptoms, but in other crops the symptoms may be less distinct or even indistinguishable. Plants of the Cucurbitaceae, including squashes, cucumbers, and cantaloups, vary greatly in the development of symptoms and in susceptibility to injury by infective beet leafhoppers. Certain squashes and cucumbers show definite curly top symptoms and are so severely damaged by this disease that they cannot be grown in areas where the beet leafhopper is present; yet cantaloups are grown commercially in these areas. Severin and Henderson (1928) mentioned that cantaloups experimentally infected with curly top showed no reliable symptoms. In 1948 the writers (Hills & Taylor 1949) demonstrated at Phoenix, in the Salt River Valley of Arizona, that cantaloup plants fed upon by curly top-infective beet leafhoppers did not necessarily develop symptoms, although growth was inhibited and yield reduced.

In 1948 only plants in the cotyledon and two-leaf stages of development were subjected to the leafhoppers, but there was some indication that two-leaf plants might be the more resistant. During 1949, 1950, and 1951 this work was continued and enlarged to include plants in the four- and six-leaf stages and also those in a more advanced stage of development.

EXPERIMENTAL PROCEDURE.—In general the procedures were the same as were used in the 1948 experiments (Hills & Taylor 1949). The cantaloup plants were Powdery Mildew Resistant No. 45, which is the most common variety grown in the Salt River Valley of Arizona. The work was done on small plantings grown on the laboratory grounds, with the exception of one experiment in a commercial field in 1951.

Infective beet leafhoppers were caged on cantaloup plants for 24 or 48 hours. Plant development and in some cases the ultimate yield and quality of fruits were observed at weekly intervals. Comparisons were made either of different strains of virus carried by the leafhoppers or of exposures of the plants in different stages of development. Insect-free plants were used as checks.

In each experiment all cantaloups were planted at the same time, and the test plants were selected for uniformity. The treatments were assigned to the individual plants by the randomized-block arrangement. Whenever a plant died from causes other than curly top, all plants of that replicate were discarded.

Cages were used only during the exposure periods. When several leafhoppers were used, they were confined within a cage that covered the whole plant. When only one leafhopper was used, it was confined on a single leaf within a small cage. Several hours before each cage was removed the plant was dusted with 2-per cent parathion to kill the insects. There were no eggs or nymphs, since beet leafhoppers do not oviposit on cantaloup plants. After all exposures were completed, the entire experimental area was dusted with parathion at approximately weekly intervals in order to maintain the plants as nearly insect-free as possible.

Fruits were classified as marketable or culls on the basis of commercial standards. The total soluble solids of the juice in each marketable fruit was then determined by use of an Abbe refractometer. The relationship between total soluble solids, sugar content, and quality of fruit has been established by Chase *et al.* (1924), who concluded that cantaloup fruits containing 10 per cent or more of total soluble solids are almost certain to

[1] N. J. Giddings, of the Bureau of Plant Industry, Soils, and Agricultural Engineering, made helpful suggestions during the progress of this work and supplied curly top-infective leafhoppers from which colonies were started.

be of good quality. In some areas this is the standard for shipment, but in others shipment of fruits containing 9 per cent of total soluble solids is allowed.

No fruit set on the plants in 1949, apparently because of the lack of pollinating insects. A colony of bees was therefore maintained in 1950 and 1951.

EXPERIMENTS IN 1949.—Two experiments were conducted in 1949. In the first experiment the effects of three strains of the curly top virus on young cantaloup plants were compared. Exposures were for 24 hours to one leafhopper, when the plants were in the cotyledon stage. The experiment was started with 15 replicates and finished with 12. Two virus strains (A and B) were obtained from stock colonies furnished by N. J. Giddings; the third strain (C) was obtained by establishing a colony on a sugar beet showing mild curly top symptoms, which was obtained from a local field. As shown in table 1, the development and yield of the plants infected with strains A and C of the virus were not significantly affected as compared with the uninfested plants. Infection with strain B reduced the size of the leaves, the length of the runners, and the number of fruits; the stunted growth of the plants was evident 6 weeks after infestation.

This experiment established the fact that virus B is especially virulent to cantaloups. Therefore, leafhoppers used in all subsequent experiments were from caged colonies carrying this strain of curly top virus.

In the second experiment in 1949 the effect of infesting cantaloup plants in the cotyledon, two-leaf, and four-leaf stages with three infective leafhoppers for 48 hours was compared. This experiment was started with 23 replicates and finished with 17. It was discontinued 7 weeks after the plants were in the cotyledon stage. Thirty-five per cent of the plants that were infested in this stage and 12 per cent of those infested in the two-leaf stage were killed by curly top, but none of the others were killed.

As shown in table 2, there was a tendency for the infected plants to be smaller. although those infested in the four-leaf stage were not significantly smaller than those not infested. The plants infested in the cotyledon stage had significantly smaller leaves than the check plants 1 week after infestation and significantly shorter runners after 3 weeks. A significant reduction in the length of runners of the plants infested in the two-leaf stage did not develop for 5 weeks.

Table 1.—Growth and yield of cantaloup plants 11 weeks after a 24-hour infestation in the cotyledon stage with single leafhoppers infective with different strains of curly top virus, 1949.

STRAIN OF VIRUS	LEAF DIAMETER	RUNNER LENGTH	FRUITS PER PLANT
	Inches	*Inches*	*Number*
A	4.0	48	1.8
B	3.0	29	0.8
C	4.3	52	1.8
Uninfested check	4.1	51	1.8
Difference required for significance ($P=0.05$)	0.6	12	0.9

Table 2.—Growth of cantaloup plants infested for 48 hours with 3 infective leafhoppers when the plants were in different stages of development, 1949.

PLANT DEVELOPMENT WHEN INFESTED	PERIOD FROM INFESTATION TO FINAL EXAMINATION	LEAF DIAMETER	RUNNER LENGTH
	Days	*Inches*	*Inches*
Cotyledon stage	49	3.8	45
Two-leaf stage	42	5.5	75
Four-leaf stage	35	5.9	88
Uninfested check	—	6.1	100
Difference required for significance ($P=0.05$)	—	1.0	20

EXPERIMENT IN 1950.—This experiment was a continuation of the second 1949 experiment. It was started with 25 replicates and finished with 24. Cantaloup plants in the same stages of development were infested for 48 hours with three leafhoppers as in 1949, but the experiment was continued for 70 days after the first infestations (50 days after the infestation of plants in the four-leaf stage) or until all plants were mature and growth had ceased.

Weekly records of runner length and leaf diameter are shown in figure 1. At the close of the experiment runner lengths of all infested plants were not only significantly less than those of the uninfested checks, but differences also occurred between the plants infested in the different stages of development. Within 20 days after infestation in the cotyledon and two-leaf stages there were significant reduc-

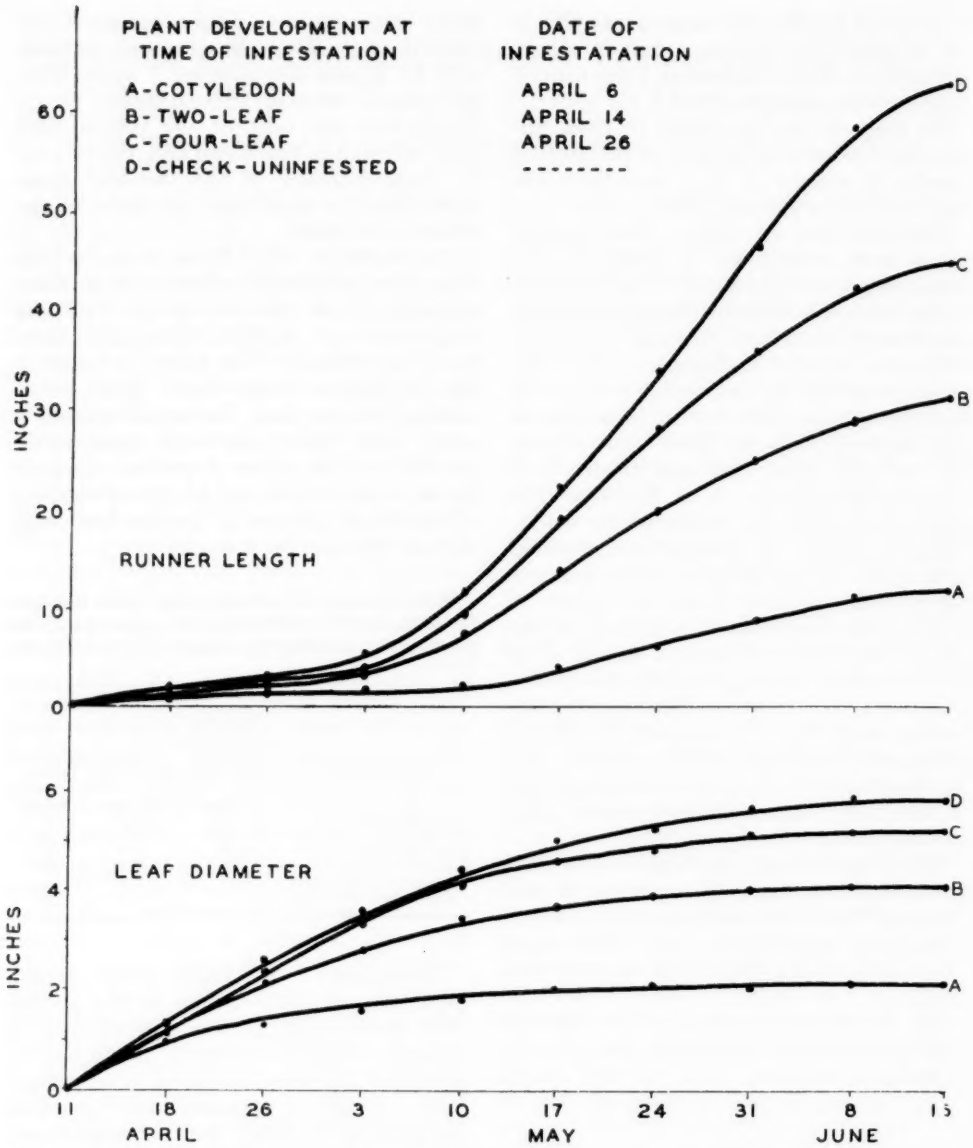

FIG. 1.—Growth rate, as indicated by runner length and leaf diameter, of cantaloup plants infested in various stages of development with curly top-infective beet leafhoppers, 1950.

tions in leaf diameter below the uninfested checks. At no time was the leaf diameter of plants infested in the four-leaf stage significantly different from that of the uninfested plants.

The percentages of plants that were killed by curly top were 80, 42, and 4 following infestation in the cotyledon, two-leaf, and four-leaf stages, respectively, as compared with no mortality of the uninfested plants. Yield data were obtained, but since so few plants remained from those infested in the cotyledon and two-leaf stages these data are of little significance.

EXPERIMENTS IN 1951.—Two experiments were conducted during the spring and summer of 1951 to determine the effect of infective beet leafhoppers on older plants, particularly on the yield and quality of the fruits. Infestations consisted of 10 infective leafhoppers over a

period of 48 hours.

The first experiment was started with 24 replicates and finished with 23. Plants having an average runner length of 8 inches were used as well as plants in the four-leaf and six-leaf stages. Measurements of leaf diameter and runner length were discontinued when the runners were approximately 30 inches long in order to prevent damage by excessive handling. As shown in table 3, plants infested in the four-leaf stage were more severely affected than those in the six-leaf stage, but there was no difference in plant growth between plants infested in the six-leaf and runner stages. Significant retardation of growth was evident 9 days after infestation in each stage, but none of the plants died from curly top. All infestations reduced not only the number of marketable fruits but also the content of soluble solids.

The second experiment in 1951 was conducted in a field of commercially grown cantaloups. Infestation in the six-leaf stage was compared with an uninfested check, in 25 replicates. None of the plants died. Measurements taken after growth had ceased, or 53 days after infestation, showed that the infested plants had smaller leaves and shorter runners (table 3). The shorter runners became evident after 18 days and the smaller leaves after 31 days. There was a slight reduction in yield of marketable fruits from the infested plants, but no appreciable difference is shown in the total soluble solids of the fruit.

SUMMARY AND CONCLUSIONS.—Experiments were conducted at Phoenix, Ariz., to determine the effect of artificially infesting cantaloup plants in varying stages of development with curly top-infective beet leafhoppers, *Circulifer tenellus* (Baker). In one experiment the effect on cantaloup seedlings of infestations of leafhoppers from colonies carrying different strains of curly top virus was studied. Some strains of the curly top virus caused more damage than others.

The earlier the stage in which cantaloup plants were infested, the more severely were they damaged. A high percentage of plants infested in the cotyledon and two-leaf stages were killed. Plants in the four-leaf stage survived but were stunted, and the yield was reduced. Plants in the six-leaf stage and those having an average runner length of 8 inches were damaged to a lesser degree, but still showed a definite retardation in growth accompanied by reduction in yield. The quality of some of the fruits was also reduced as shown by a reduction in the total soluble solids in the juice.

This build-up of resistance in older plants may account for the fact that cantaloups can be grown in areas where some of the other cucurbits are killed by curly top, but it does not mean that the

Table 3.—**Growth of plants and yield and quality of fruits from cantaloup plants infested for 48 hours with 10 infective leafhoppers when the plants were in different stages of development, 1951.**

Plant Development When Infested	Period from Infestation to Final Examination	Leaf Diameter	Runner Length	Fruits per Plant		Soluble Solids
				Marketable	Culls	
	days	*inches*	*inches*	*number*	*number*	*per cent*
Experiment 1:						
Four-leaf stage	27	3.3	10	0.1	0.3	7.3[1]
Six-leaf stage	22	4.5	28	1.1	0.6	9.0
Runners 8 inches long	16	4.5	30	1.8	0.8	9.2
Uninfested check	—	4.9	34	2.5	0.9	10.4
Difference required for significance ($P=0.05$)	—	0.3	3	0.5	0.3	1.1
Experiment 2:						
Six-leaf stage	53	4.7	47	1.8	0.4	10.6
Uninfested check	—	5.0	53	2.3	0.2	10.4
Difference required for significance ($P=0.05$)	—	0.2	4	0.4	[2]	[2]

[1] Not included in the statistical analysis, since only 4 plants produced fruit.
[2] Not significant by the *F* test.

crop may not suffer loss from the disease.

These experiments also indicate that severe damage can result from leaf-hopper migrations before the plants reach the six-leaf stage. The fact that retardation of growth and reduction in yield may follow beet leafhopper infestations without producing recognizable symptoms further complicates the problem and indicates the possibility of a reduction in yield not ordinarily attributed to curly top.

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Some Effects of Aldrin, BHC-DDT, Dieldrin, and Toxaphene on the Boll Weevil[1]

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An examination of the recommendations being made for the control of the boll weevil, *Anthonomous grandis* Boh., readily shows that at least four organic insecticides are generally recognized as being approximately equally effective in producing increases in yield of seed cotton. A choice between these insecticides would then appear to depend on certain desirable characteristics such as the different kinds of pests against which they are effective, cost, rate at which they kill, effectiveness after rainfall, etc.

Gaines & Dean (1949) reported that the toxicities of chlordane-sulfur, toxaphene-sulfur and 3 per cent BHC-5 per cent DDT-sulfur (3–5–40) mixtures were affected by temperature and humidity. Toxaphene was the least affected of the three mixtures. Gaines & Mistric (1951) found, under laboratory conditions, that 0.5 inch rain did not affect the toxicity of either toxaphene or dieldrin spray formulations but that of aldrin was reduced. They further assumed that relative humidity, sunshine, dew and wind are important factors under field conditions since higher dosages are required than under laboratory conditions to get comparable control.

The present work was undertaken to determine the following points under laboratory conditions: (1) the period of exposure required for lethal dosages of aldrin, BHC-DDT mixture, dieldrin, and toxaphene to cause paralysis and death of the boll weevil; (2) the effect of rainfall on the effectiveness of these poisons, including four different dust formulations of toxaphene; (3) the effect of lethal dosages of toxaphene on the feeding and oviposition of female weevils between treatment and death.

MATERIALS AND METHODS.—Delta and Pine Land Number 15 cotton seed was planted in a good grade of top soil in soil collecting boxes, 2 by 3 by 4 inches. When the first three permanent leaves had formed, the seedlings were transplanted into 10-inch clay flowerpots and 1-gallon tin cans. The media for growing the potted plants consisted of 3 parts sandy loam top soil, 1 part sand, and 1 part peat moss. For good drainage, approximately 0.75 inch of pea gravel was placed on the bottom of each container. To prevent the tap root from growing into the ground, the hole in the bottom of the flowerpots was covered.

Beginning 2 weeks after transplanting,

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weekly applications of *Hyponex* were made, 0.25 teaspoonful before fruiting, 0.5 teaspoonful when fruiting began, and 1 teaspoonful when heavy fruiting began. The fertilizer was applied directly to the soil and then watered in, two waterings being required when large amounts were applied. Squaring began in approximately 6 weeks and the plants were fruiting heavily in 8 weeks.

The boll weevils used in the tests were field-collected, and none were taken from fields which had been treated with insecticides later than 2 weeks before collection. The insects were not held more than 1.5 days before using, and, in a particular test, all weevils used were collected from the same field. Determination of sex was not attempted except in oviposition tests, where only females collected in copula were used.

The insecticides were commercially available sprays and dusts. For applying the sprays, a conventional 3-gallon compressed-air sprayer equipped with a pressure guage was used. A single *TeeJet* nozzle delivering 1 gallon per hour at 40 p.s.i. was used. This nozzle delivered a cone shaped spray pattern through an orifice 0.0175 inch in diameter.

To attain the desired rate of application, a 22-foot spray path was marked off. The plants were placed on the path, and one pass was made with the sprayer in 5 seconds. This corresponded to a rate of 1 gallon of spray solution per acre, and the solutions were of such dilutions that the insecticides, aldrin, BHC-DDT, dieldrin, and toxaphene, were applied at recommended dosages. The parts of the plants sprayed were the same as those sprayed when three nozzles per row are used.

For the dusts, a dusting tower 5 feet high was used in the initial attempt. The insecticide was blown downward onto the plant by one quick blast from a manually operated foot pump. This method proved unsuccessful due to very poor coverage. The dusting tower was then modified so as to be $90 \times 18.5 \times 18.5$ inches. The insecticide was placed in a $\frac{1}{2}$-inch condenser tube bent into a sharp S-shape. The tube was placed in the center of the tower 50 inches from the bottom. The dust was then blown upward by one quick blast of a pump and allowed to settle for 5 minutes. Good coverage was obtained by this procedure.

To simulate rainfall, a rectangular-shaped sprinkler fastened to a common garden hose was used. The end of the hose and sprinkler were fastened to a bipod which was adjustable so that the angle and height of water could be controlled. The water was directed up at about a 75 degree angle and allowed to fall on the cotton plant. After several methods were tested, it was found that the use of a stop watch was the best method of getting the same amount of simulated rainfall on each plant. This method resulted in only a fraction of an inch difference in rainfall on the different plants. The amount of simulated rainfall was determined by placing four 1-quart oil cans with a sharp-edge top around the potted plant and just outside the drip area of the plant. The water was measured in milliliters and converted into inches. The average amount of water caught by the four cans was used as the rainfall per plant. The time required for the sprinkler to deliver the desired amount of water under constant pressure was pre-determined. Minor differences in the amount of water sprayed on different plants occurred.

The plants were enclosed in screen wire cages, $2 \times 2 \times 2$ feet in size. The bottoms of the cages consisted of two pieces of masonite, which, when fitted together, provided a center hole through which the stem of the plant could extend. Cotton plugs were used to insure against escape of the insects. A door was provided on one side of each cage.

The caged plants were placed in an outdoor rack, 35 feet long, 5 feet wide, and 5 feet high, having a supporting framework 2 feet above the ground. Each cage was so arranged that there was 1 foot clearance in all directions. The rack was covered by removable hotbed sashes sloped to permit drainage. Heavy domestic cotton sheeting, which could be dropped during rains, was installed on the sides. The potted plants were placed on the ground or on blocks, depending on the size of the plants.

The speed of kill of the several insecticides, and the effect of rainfall on them, were determined in the same experiment. For each formulation, either spray or dust, two plants were treated. One of these was subjected to approximately 0.5 inch of simulated rainfall. Two untreated plants were used as checks. The plants were

Table 1.—Summary of tests on effect of simulated rain on control by insecticides applied as sprays. State College, Miss. 1952.

Treatment	Dosage per Acre	Simulated Rainfall in Inches	Cumulative Percentage Control by Days as Compared with Checks of Individual Days					Average Number of Weevils per Test
			1st	2nd	3rd	4th	5th	
Aldrin[1]	0.25	0.0	8.7	16.4	22.9	26.1	30.2	23.2
Aldrin[2]	0.25	0.5	− 0.2	9.2	14.2	14.4	20.1	23.0
BHC-DDT[1]	0.4	0.0	10.9	22.9	23.2	24.1	24.8	23.2
BHC-DDT[2]	0.4	0.49	2.7	6.0	4.0	5.2	4.5	22.7
Dieldrin[1]	0.15	0.0	16.1	32.7	42.9	49.8	52.4	22.8
Dieldrin[2]	0.15	0.51	22.1	38.0	48.2	52.4	51.9	22.5
Toxaphene[1]	2.5	0.0	21.9	53.3	55.7	61.7	64.6	23.3
Toxaphene[2]	2.5	0.51	17.2	34.6	42.9	44.8	44.9	23.3

[1] No rain.
[2] Rain (simulated).

caged and the weevils were released within the cases. Twenty-five weevils per plant were used, except in a few instances where availability made it necessary to use only 20. The plants were inspected daily, at which time the effect on the weevils was recorded. The percentage control was calculated according to Abbott's formula. The tests were repeated six times for each formulation. All variables were kept as constant as possible throughout.

The same procedure was used to determine the effect of rainfall on different dust formulations of toxaphene.

In the oviposition and feeding tests, toxaphene, both as a spray and a dust, was the only insecticide used. Female weevils were used exclusively. In these tests, the plant was treated, caged, and 40 weevils were introduced into the cage. Ten weevils (only those on the plant were considered) were taken from the cage at the end of 2, 4, 6, and 8 hours of exposure. Each of the weevils was placed in a clean ½-pint jar covered with a wire screen along with two half-grown squares obtained from untreated plants which were replaced by fresh squares at 24 hour intervals. Feeding and oviposition punctures were recorded for the exposed squares. Each test was run for 5 days. If, at the end of 5 days, the weevil was not dead, it was recorded that a lethal dose had not been received. Ten weevils were used on untreated plants to serve as a check on natural mortality. This test was repeated four times for each formulation.

RESULTS.—Table I gives a summary of the data from the tests to determine the effect of rainfall on spray formulations of the four chlorinated insecticides. The data from plants not subjected to simulated rainfall show that of the four insecticides tested toxaphene gave the best control and was the fastest acting, followed by dieldrin. Neither BHC-DDT nor aldrin showed the quick acting affect usually attributed to them. The conditions under which the experiments were conducted were not favorable for any direct fumigating effect. However, according to Mistric & Rainwater (1950) the value of this type of action under field conditions is questionable. The concentrations, exposure period and per cent kill obtained from "fumigation through plant absorption of

Table 2.—Effect of simulated rain on control by insecticides applied as sprays. State College, Miss. 1952.

Treatment	Pounds Toxicant per Acre	Per Cent Control		Per Cent Reduction Due to Rain	Inches of Rain
		No Rain	Simulated Rain		
Aldrin	0.25	30.2	20.1	33.4	0.51
BHC-DDT	0.4	24.8	4.5	81.9	0.49
Dieldrin	0.15	52.4	51.9	1.0	0.51
Toxaphene	2.5	64.6	44.9	30.5	0.51

Table 3.—Summary of the effect of simulated rain on control by insecticides applied as dust. State College, Miss. 1952.

Treatment	Dosage per Acre	Simulated Rainfall in Inches	Cumulative Percentage Control by Days					Average Number Weevils per Test
			1st	2nd	3rd	4th	5th	
Aldrin[1]	0.31	0.0	7.5	19.5	23.4	28.4	37.8	24.0
Aldrin[2]	0.31	0.50	1.1	6.3	12.2	12.5	13.4	24.0
GBHC[1]	0.48	0.0	11.4	31.0	42.7	48.0	48.7	23.7
GBHC[2]	0.48	0.50	0.8	3.1	7.7	13.2	13.7	24.3
Dieldrin[1]	0.19	0.0	24.3	37.9	47.9	51.6	57.9	24.5
Dieldrin[2]	0.19	0.51	3.1	20.0	27.9	36.4	41.7	22.8
Toxaphene[1]	2.5	0.0	31.5	55.9	65.5	67.7	72.4	24.0
Toxaphene[2]	2.5	0.50	4.3	11.7	23.6	28.3	37.8	24.0

[1] No rain.
[2] Rain (simulated).

vapors or condensation of vapors on plant surfaces" (Mistric & Rainwater 1950) also suggest that the value of this type of action is questionable under field conditions.

Dieldrin gave the best control and was the fastest acting insecticide following simulated rain. It was followed by toxaphene both in effectiveness and rate of action. The effect of simulated rain on BHC was particularly striking in that the insecticide was ineffective after the second day.

The reduction in effectiveness of the insecticides (Table 2), due to simulated rainfall was calculated from the data in Table 1. Dieldrin was the least affected and lindane the most. Aldrin and toxaphene were approximately the same. However, control obtained by the use of toxaphene was much better than with aldrin.

Tests with the dusts (Tables 3 and 4), where no simulated rain was applied, showed a trend toward a higher degree of control than with the sprays. It should be noted that slightly more aldrin, BHC and dieldrin were applied as dusts than as sprays, whereas the toxaphene was maintained at the same level as in the spray. Toxaphene gave the best control. The initial control was also best. Dieldrin, as in the sprays, was the next most effective. The marked increase in the control obtained with the BHC dust may have been due to either the increased amount over that of the spray or to the source of the effective isomer.

Simulated rain reduced the control of all the insecticides, except BHC, more when they were used as dusts than as sprays. This was shown in the percentage reduction in the control as compared with that where no simulated rain was applied.

Table 5 shows the control obtained from different dust formulations of toxaphene when subjected to simulated rainfall. Mixture 1 (toxaphene 20%, *Attaclay* 30%, sulfur 40%, and bentonite 10%) gave a slightly better control than the other mixtures when not subjected to rainfall, however, its effectiveness was greatly reduced by simulated rainfall. Mixture 3 (toxaphene 20%, *Attaclay* 30% and *Pyrax* 20%) was not as effective in these tests as mixture 1 in the absence of rainfall but was more effective after being subjected to 0.52 inch of simulated rainfall, showing the need for further study.

The oviposition and feeding data from

Table 4.—The effect of simulated rain on control obtained by insecticides applied as dust. State College, Miss. 1952.

Treatment	Pounds Toxicant per Acre	Per Cent Control		Per Cent Reduction Due to Rain	Amount of Rain
		No Rain	Simulated Rain		
Aldrin	0.31	37.8	13.4	64.5	0.50
GBHC	0.48	48.7	13.7	51.3	0.50
Dieldrin	0.19	57.9	41.7	28.0	0.51
Toxaphene	2.5	72.4	37.8	47.8	0.50

Table 5.—Effect of diluents used on control and residual effect of toxaphene[1] under simulated rain.

Mixtures: Toxaphene, 20% Attaclay, 30% plus	Test Number						Average	Simulated Rainfall in Inches
	1	2	3	4	5	6		
Sulfur 40% Bentonite 10%[2]	82.6	80.0	75.0	68.0	30.4	66.0	67.0	
Sulfur 40% Bentonite 10%[3]	17.1	15.0	10.0	− 5.2	4.3	11.9	8.9	0.51
Kaolin 50%[2]	65.1	70.0	50.0	47.4	56.5	27.7	58.8	
Kaolin 50%[3]	4.0	− 5.0	− 5.0	10.5	− 8.7	19.0	2.1	0.53
Pyrax 50%[2]	82.6	65.0	65.0	58.0	47.8	31.9	58.4	
Pyrax 50%[3]	60.7	22.3	35.0	0.0	0.0	24.3	23.7	0.52
Talc 50%[2]	86.9	60.0	45.0	42.0	39.1	57.4	55.1	
Talc 50%[3]	12.8	− 5.0	0.0	0.0	8.7	19.1	5.9	0.53

[1] Tested at 2.5 pounds active ingredient per acre.
[2] No rain.
[3] Rain (simula

experiments with toxaphene sprays and dust, (Tables 6 and 7) clearly show that exposure to toxaphene greatly reduces the tendency of female weevils to feed and oviposit, even following exposures as short as 2 hours.

Conclusions.—The data obtained under laboratory conditions indicate that:

Toxaphene and dieldrin gave appreciably better control of boll weevils than aldrin or BHC-DDT when applied either as a dust or spray.

BHC-DDT gave better control as a dust than as a spray. Dust formulations of aldrin, dieldrin and toxaphene tended to give better control than sprays.

Table 6.—Effect of toxaphene applied as a spray on feeding and oviposition as related to hours' exposure. State College, Miss. 1952.

Tests	Exposure (Hours)	Pounds Toxicant per Acre	Female Weevil, Days	No. Punctures per Weevil Day	
				Feeding	Oviposition
1	2	2.5	12	0.92	0.08
2	2	2.5	7	0.43	0.00
3	2	2.5	4	2.00	0.00
4	2	2.5	0	0.0	0.00
Average	2	2.5	6	0.84	0.02
1	4	2.5	7	0.43	0.14
2	4	2.5	4	1.00	0.00
3	4	2.5	1	4.00	3.00
4	4	2.5	3	2.00	1.00
Average	4	2.5	3.75	1.86	1.04
1	6	2.5	9	1.44	0.11
2	6	2.5	7	0.43	0.00
3	6	2.5	4	0.25	0.25
4	6	2.5	5	1.00	1.40
Average	6	2.5	6.25	0.78	0.44
2	8	2.5	12	4.12	0.00
3	8	2.5	2	0.00	0.00
4	8	2.5	1	2.00	0.00
Average	8	2.5	5.0	2.04	0.00
Check					
1	0	0	41	6.68	0.63
2	0	0	39	5.79	1.18
3	0	0	49	3.90	0.96
4	0	0	50	4.26	1.00
Average			44.75	5.17	0.94

Table 7.—**Effect of toxaphene applied as a dust on feeding and oviposition as related to exposure period. State College, Miss. 1952.**

Tests	Exposure (Hours)	Pounds Toxicant per Acre	Female Weevil, Days	No. Punctures per Weevil Day	
				Feeding	Oviposition
1	2	9.6	10	0.20	0.40
2	2	9.6	10	0.30	0.10
3	2	2.5	10	0.30	0.10
4	2	2.5	9	0.22	0.00
Average			9.75	0.26	0.15
1	4	9.6	11	1.73	0.18
2	4	9.6	11	0.73	0.27
3	4	2.5	15	1.33	0.33
4	4	2.5	17	1.70	0.24
Average			13.5	1.37	0.26
1	6	9.6	18	2.61	0.56
2	6	9.6	8	3.62	0.38
3	6	2.5	11	1.36	0.18
4	6	2.5	14	1.00	0.14
Average			12.75	2.15	0.32
1	8	2.5	6	0.00	0.00
Check					
1	0	0	33	10.00	1.79
2	0	0	20	10.40	1.95
3	0	0	38	7.21	1.89
4	0	0	46	8.86	1.39
Average			34.25	9.12	1.76

Toxaphene gave better and faster control than the other insecticides when not subjected to simulated rainfall.

One-half inch of simulated rainfall significantly reduced the control by all insecticides when applied as a spray or dust, except in the case of dieldrin applied as a spray. Dieldrin and toxaphene gave almost the same control after exposure to 0.5 inch of simulated rain.

A dust formulation containing 20 per cent toxaphene, 30 per cent *Attaclay*, and 50 per cent *Pyrax* was reduced in activity by simulated rainfall to a lesser extent than three other dust formulations.

The egg-laying and feeding activities of female boll weevils were reduced by exposure to lethal dosages of toxaphene even when exposed for only 2 hours.

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Insecticide Dusts for Control of the Western Grape Leaf Skeletonizer in California[1]

M. M. Barnes,[2] C. Gammon,[3] and D. W. Robinson[3,4]

Following the discovery of an infestation of the western grape leaf skeletonizer, *Harrisina brillians* B. & McD., near Alpine, San Diego County, California, in 1941, and its subsequent spread to adjacent areas, a program was initiated by the Bureau of Entomology of the California State Department of Agriculture, in 1945, directed toward possible eradication of this insect or suppression and prevention of its spread to other areas in the state (Armitage 1945). In support of these objectives, and in order to develop information concerning the species for use in the eventuality of its spread to the major grape-growing areas of the state, studies on the biology, ecology, and chemical control of this insect were undertaken by the Department of Entomology of the University of California at Riverside on a cooperative basis with the State Bureau of Entomology. Information on the life history and seasonal history of the skeletonizer has been summarized by Robinson (1950). Studies with moth attractants are reported by Barnes *et al.* (1954).

The larvae of the western grape leaf skeletonizer are gregarious. Larvae of the first three instars feed side by side in large colonies on the under surface of the leaf. Larvae of later instars are usually grouped in smaller colonies and eat the entire leaf excepting the main veins, although these may be eaten when most of the leaves have been thoroughly skeletonized.

On the basis of preliminary trials by Dr. A. M. Boyce (Lange 1944), a 50 per cent cryolite dust was used in the treatment of known infested areas as a holding program in 1945. Very satisfactory control was obtained. An unreplicated small-scale trial in 1945 had indicated that a dust containing 5 or 10 per cent DDT might have considerable value in this connection. Further studies were required for selection of the best material for use in a suppression program and for use by vineyardists if infestations spread to other areas.

Trials with Cryolite and DDT Dusts, 1946–47.—The comparative efficiency of cryolite and DDT dusts was evaluated in the following trials. In 1946, in a 22-acre Zinfandel vineyard at Alpine, California, eight replicates of 5 and 10 per cent DDT dust and seven replicates of 50 per cent cryolite dust were applied with a power duster in randomized blocks on July 4 and on August 1 at a rate closely approximating 25 pounds per acre.

Infestation counts were made 1 week after the first application and on seven occasions thereafter, at intervals of from 10 days to 3 weeks. Eighty tagged vines were closely examined in each plot on each counting date. Records were taken of (1) the total number of vines bearing skeletonizer injury, (2) the number of active old colonies (larvae usually beyond second instar), and (3) the number of active newly hatched colonies. These data are presented in table 1.

The initial infestations of the plots of the three treatments were similar, and this indicated that the number of replications employed was adequate. The first counts, on July 11, showed 59, 54, and 56 infested vines out of a total of 640 for treatments with 5 per cent DDT, 10 per cent DDT, and 50 per cent cryolite, respectively. The data in table 1 also show the development of infestation in plots of each treatment and provide an indication of the relative effectiveness of the treatments in providing residual protection. With respect to the latter, attention is directed to the number of active old colonies present in the various treatments on July 29, 3 weeks after the first application. The cryolite-treated plots had the lowest number of larval colonies apparently proceeding to maturity, followed by the 10 per cent and 5 per cent DDT-treated plots, in that order. Similarly, it will be noted that, in the period following the second application, the treatments fall in the same order with respect to residual control.

Results of the trial indicate that al-

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[4] The authors acknowledge the assistance of C. L. Turzan, R. P. Allen, and Harold Green in these trials.

Table 1.—A comparison of DDT with cryolite for control of the western grape leaf skeletonizer, Alpine, 1946.[1]

Date of Count	Total no. of Vines Showing Feeding Injury			Number of Colonies with Live Larvae					
				Old Colonies[2]			Newly Hatched Colonies		
	DDT 5%	DDT 10%	Cryolite 50%	DDT 5%	DDT 10%	Cryolite 50%	DDT 5%	DDT 10%	Cryolite 50%
First Application, July 4[3]									
7/11	59	54	56	2	4	3	6	6	11
7/19	67	80	61	9	14	5	17	18	9
7/29	102	92	82	24	13	8	10	19	13
Second Application, August 1[3]									
8/8	104	96	86	1	1	1	1	0	1
8/19	107	103	95	1	1	0	1	2	0
8/30	108	103	95	1	3	0	1	1	0
9/20	108	104	96	2	0	0	2	1	1
10/15	109	104	97	3	0	0	0	0	0
Total				43	36	17	38	47	35

[1] Data derived from an examination of 560 to 640 vines per treatment; corrected on the basis of the latter number for comparison. Pyrolite (a pyrophyllite) used as a diluent for the DDT dusts. Cryolite dust commercially prepared.
[2] Active old colonies consisted in most cases of a few larvae, only.
[3] With Noble power duster; 25 pounds per acre.

though either a 5 per cent or 10 per cent DDT dust may provide commercial control, a 50 per cent cryolite dust performs somewhat better from the standpoint of the purposes of eradication or abatement.

In another trial in 1947 a study was made of the relative effectiveness of 50, 60, and 75 per cent cryolite, as compared with 10 per cent DDT. These dusts were applied at the rate of 25 pounds per acre to four replicates of approximately 120 vines each in a Muscat of Alexandria vineyard at El Cajon. Applications were made on June 20 and July 22 with a jeep-mounted power duster.

Counts of the number of colonies on an average of 50 vines in each replicate were made at the time of the first application, on June 20, and 10, 17 and 24 days thereafter, as shown in table 2. The average infestation at the time of application varied considerably among plots of the four treatments. Data obtained subsequently are therefore expressed as percentages of colonies alive. Control of the first-generation larvae was virtually complete in all plots 17 days after the first application.

A considerable proportion of the first-generation larvae had pupated prior to the first treatment and the moths emerged and oviposited between treatments. No new colonies were observed during the first 24 days after the first application. Unusually large numbers of moths were observed in the vineyard on July 7, and eggs were observed on and after that date. The application on July 22 completely prevented the development of this infestation, according to counts made July 30 and August 12 and not shown in table 2. According to Robinson (1950), the average duration of the pupal stage of this insect is approximately 20 days. The heavy second-generation moth flight in these trials thus came from pupation occurring but 3 or 4 days prior to the first application. This indicates the importance of timing in making this application. Larval mortality was somewhat more rapid in the plots treated with 60 and 75 per cent

Table 2.—A comparison of cryolite dusts of varied concentrations with DDT for control of the western grape leaf skeletonizer, El Cajon, 1947.

Dust[1]	Per Cent Vines Infested[2] 6/20	Per Cent Colonies with Live Larvae (Days After Treatment) 10	17	24
1. Cryolite, 50%	10	25	0	0
2. Cryolite, 60%	13	14	0	0
3. Cryolite, 75%	31	16	1	0
4. DDT, 10%	18	2	0	0

[1] Pyrolite, (a pyrophyllite) used as a diluent for all dusts. Treatments were applied with a power duster at 25 pounds per acre on June 20 and July 22; four replications.
[2] Approximately 200 tagged vines of each treatment were examined on each of the four counting dates. No live colonies were found after second application (see text).

cryolite than in those treated with 50 per cent cryolite, but there appeared to be little advantage in increasing the percentage of cryolite above 50 per cent, since ultimate control was apparently complete in all cases.

Twelve days after the dust applications reported in table 2 were made, 139 pupae were collected from under the bark and in soil adjacent to two vines dusted with 60 per cent cryolite. Only 14 of these pupae emerged. In control groups of pupae collected at approximately the same time, on and adjacent to undusted wild vines, emergence was 98 per cent. The dead pupae from the cryolite-dusted vines and the control pupae were analyzed for fluorine.[5] These analyses showed 62 p.p.m. fluorine in pupae from the cryolite-dusted plants as compared with none in the controls. This suggests that a lethal dose of cryolite acquired in the larval stage does not prevent pupation. It is noted, also, that following applications of cryolite against a population of mature larvae, some of these would pupate before feeding sufficiently to acquire a lethal dose.

Mortality of larvae of the western grape leaf skeletonizer was much more rapid with DDT than with cryolite. In a suppression program there would thus be an advantage in the use of DDT where large numbers of larvae are almost ready to pupate. Possible interference with potential biological control is a factor that should be considered before using DDT, however.

TRIALS WITH OTHER DUSTS, 1948.—Should the western grape leaf skeletonizer become established in the major grape-growing areas of California, the use of either cryolite or DDT would involve a residue problem on early varieties. Several materials which would be less objectionable in this respect, and which, if they proved superior to cryolite, might be useful in a holding program in the known infested area, were tried in 1948.

By 1948, populations had been largely confined to canyons and creek bottoms in which wild grapevines were present, no cultivated vineyards with significant populations being available for use in insecticide trials. At Lakeview, a portion of Los Coches creek bottom was used for trials comparing the effectiveness of TDE, methoxychlor, ditolyltrichloroethane, and parathion with that of 50 per cent cryolite and 5 per cent DDT. The 5 per cent level of DDT was used for this comparison, since differences among DDT and its analogs might be more apparent at this concentration.

Table 3.—Trials with dusts which would involve less of a residue problem than cryolite or DDT for control of western grape leaf skeletonizer, Los Coches Creek, 1948.[1]

Dust[2]	Date of Count	Total Colonies	Estimated Larvae	Per Cent Colonies with Live Larvae
TDE, 5%	6/23	43	805	86
	7/19	337	3140	68
	8/9	242	60	2
	8/30	146	95	5
TDE, 10%	6/23	38	380	47
	7/19	699	3495	34
	8/9	274	0	0
	8/30	142	190	7
Methoxychlor, 5%	6/23	11	125	45
	7/19	114	685	36
	8/9	74	0	0
	8/30	81	0	0
Methoxychlor, 10%	6/23	3	0	0
	7/19	39	185	28
	8/9	27	0	0
	8/30	17	15	6
Ditolyltrichloroethane, 10%[3]	6/23	192	3250	72
	7/19	104	850	52
	8/9	134	95	11
	8/30	172	415	15
Parathion, 1%	6/23	317	4345	66
	7/19[4]	326	2875	52
	8/9	363	575	22
	8/30[4]	217	470	10
DDT, 5%	6/23	23	210	52
	7/19	60	405	42
	8/9	82	0	0
	8/30	77	125	6
Cryolite, 50%	6/23	182	3640	88
	7/19	1298	12780	53
	8/9	340	5	0
	8/30	380	175	2

[1] Treatments applied June 16 and July 21 with rotary hand dusters to three replicates on wild vines.
[2] Pyrolite (a pyrophyllite) used as a diluent.
[3] Geigy Company, Inc.
[4] Since relatively large numbers of surviving larvae were present, counts were made on two plots, only.

An area in the creek bottom in which wild grapevines were present was flagged off into 24 segments, and the eight insecticidal dust treatments listed in table 3 were applied in three randomized blocks. Application was by rotary hand duster, and all vine foliage that could be dusted from the ground was given treatment simulating routine usage at approximately 25 pounds per acre. Since there were gross differences among the plots in the amount of wild grape foliage present, rates of application actually used could not be measured or compared among treatments.

[5] Analyses by California State Department of Agriculture, Bureau of Chemistry.

Applications were made on June 16 and July 21. Counts were made 1 week after the first treatment, immediately prior to the second treatment, and 3 weeks and 6 weeks after the second treatment. These data are recorded in table 3. Records were made of the number of colonies, dead and alive, found in each plot, and of the approximate number of larvae surviving.

It should be recognized in interpreting these data that detection of colonies depended to some extent upon the presence of sufficient feeding injury. In plots of a treatment providing a high degree of residual contact action, fewer colonies would be detected, since mortality of newly hatched larvae would occur to some extent before a significant amount of feeding took place. The limited replication and the variations between plots in amounts of vine foliage and shading, and in other factors affecting the attractiveness of a given plot to ovipositing moths, all contribute to a conservative interpretation of this trial. The percentage of colonies alive on August 9 is probably the most significant count, since it was taken 3 weeks after the second application. The data taken August 30 recorded some late reinfestation.

The high infestation recorded for the cryolite plots is due in part to the slower mortality provided by this material, in comparison with some of the other materials, permitting the detection of more colonies; it is probably due in part, also, to a heavier infestation because of greater density of vine foliage in these plots. Cryolite provided very good eventual mortality. The trace survival in the cryolite plots is probably related to the difficulty of obtaining good coverage of the grapevines in this creek-bottom location. The DDT plots were by chance located adjacent to the cryolite plots, and the lower incidence of colonies in the DDT plots is probably related to more rapid kill of newly hatched colonies, so that some of these were not detected. DDT provided very good control, there being no survival 3 weeks after the second dusting.

Methoxychlor provided very good control and appeared to be as effective as DDT. TDE also provided a promising degree of control, though at the 5 per cent level it was not so effective as DDT. Parathion and ditolyltrichloroethane did not provide satisfactory control as employed.

SUMMARY.—Trials with cryolite and DDT dusts conducted over a period of three seasons indicate that although a 5 or 10 per cent DDT dust would provide commercial control of the western grape leaf skeletonizer, *Harrisina brillians* B. & McD., 50 per cent cryolite would apparently be superior from the standpoint of general use in an abatement program, since it provided very good ultimate mortality, good residual control, and would be less likely to interfere with potential biological control. In one trial there appeared to be little advantage in increasing the concentration of cryolite above 50 per cent, from the standpoint of eventual mortality. Where a significant proportion of mature larvae are present, DDT would be superior to cryolite, since the larvae may not in all cases acquire a lethal dose of cryolite in a relatively short feeding period.

Methoxychlor and TDE provided a promising degree of control and may be considered as worthy of trial in situations involving a residue hazard. Parathion and ditolyltrichloroethane were not effective.

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Attractants for Moths of the Western Grape Leaf Skeletonizer[1]

M. M. Barnes,[2] D. W. Robinson,[3] and A. G. Forbes[4,5]

In support of efforts to prevent the spread of the western grape leaf skeletonizer, *Harrisina brillians* B. & McD., from an infested area in San Diego County in southern California to the major grape-growing areas of the state (Armitage 1945, Barnes *et al.* 1954), studies with potential moth attractants have been conducted during four seasons. In surveys to determine the effectiveness of restrictive procedures adopted in the known infested area and along its borders, detection of the presence of this insect in peripheral areas is dependent upon visual observation of skeletonized foliage or of the metallic blue-black diurnal moths. The development of an effective attractant would therefore materially increase the efficiency of survey work.

The female grape leaf skeletonizer moth oviposits almost exclusively on grapevines. Larvae have also been found, however, on Virginia creeper and Boston ivy. The adults live from 4 to 8 days. They may feed, but feeding probably does not always occur or need to occur. Adults have been observed visiting flowers of horehound (*Marrubium vulgare*), yerba mansa (*Anemopsis californica*), sweet William (*Dianthus barbatus*), and grapefruit (*Citrus grandis*). There are two complete generations and a partial third generation each year. Details of the biology of this species are reported by Robinson (1950).

In interpreting results of these trials, it must be understood that many of the trials were conducted, as planned, in areas where, or during periods when, moths were present in relatively low numbers. Thus total catches in certain cases appear to be somewhat small. Although an attractant suitable in all respects for survey work has not as yet been developed, considerable progress has been made.

Materials and Methods.—The attractant values of more than 50 materials were studied by placing them in water-filled fiberboard pails hung on wires strung across stream beds along which wild grapevines were abundant. Five replications of each material were commonly used in randomized blocks. The pails were of 1-quart capacity and tapered from 6 inches in diameter at the top to 5 inches in diameter at the bottom, over a 6-inch depth. Other types of traps used for female moth extractive studies are described below.

The source and purity of the attractant materials used are given in the tables. As noted hereinafter, in one trial attractant materials were not formulated; in other trials, before being added to the traps, these materials were emulsified as described in tabular footnotes.[6]

Preliminary Trials, 1946.—Studies were begun in 1946 with exploratory trials of typical attractant materials. In the first of these trials diamalt and a refinery syrup, each at 5 per cent in water, were tried alone and with terpinyl acetate or oil of sassafras at 3 cc. per trap. The traps were placed in an area where numerous moths were present, and were observed over a 2 weeks' period. These materials proved to have no attractant value for moths of the western grape leaf skeletonizer.

In the trial that followed, 16 additional, unformulated materials were used at the rate of 5 cc. per trap. These materials included several essential oils, essential oil constituents, and miscellaneous esters (Table 1).[7] This trial was conducted in an unreplicated series in an area in which there was a high moth population. Anisaldehyde, oil bergamot, and citral were clearly attractive, and the fact that some moths responded to most of the materials

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[5] The authors acknowledge the assistance of Cyril Gammon and W. M. Pearce, both of the California Department of Agriculture, Bureau of Entomology, in conducting these investigations.

[6] Emulsifying materials used were *Bentonite No. 49*, Whittaker, Clark & Daniels, Inc. (see footnote 1, Table 2); or *Triton X-100*, Rohm & Haas Company, Inc. (see footnote 2, Table 3).

[7] The authors are indebted to Dr. Glenn E. Carman for supplying the materials used, and to Mr. Fred Thorne for all trap observations made in 1946.

Table 1.—**Results of a preliminary trial of potential attractants for moths of the western grape leaf skeletonizer, Sweetwater Road, California, 1946.**

MATERIAL[1]	TOTAL MOTHS TRAPPED, JULY 31 TO AUG. 20
Anisaldehyde[2]	32
Citral (pure)[3]	27
Oil bergamot (imitation)[4]	27
Oil of star anise (U. S. P.)[5]	15
Oil of eucalyptus[6]	13
Ethyl phthalate[2]	10
Oil of fennel (U. S. P.)[4]	9
Ethyl cinnamate (C. P.)[3]	7
Oil of mace[4]	5
Terpineol[7]	4
Safrole[2]	3
Methyl acetate (C. P.)[3]	2
Isopropyl salicylate[8]	1
Isopropyl acetate[8]	1
Anethol[9]	0
Eugenol[7]	0

[1] Unformulated: added at the rate of 5 cc. per water-filled trap.
[2] Eastman white label (highest purity).
[3] Fisher Scientific Co.
[4] Horton & Converse.
[5] Fritzsche Bros.
[6] Western Wholesale Drug Co.
[7] Merck & Co., Inc.
[8] Source unknown.
[9] Pfaltz & Bauer.

tried indicated that further studies should be made.

TRIALS WITH VARIOUS MATERIALS, 1947–1950.—In 1947, five of the materials used in the preliminary trials of 1946 were recompared, and three additional materials were tried. These were studied in two series in different locations. Results (Table 2) indicate that attractant values for oenanthic ether and anisaldehyde were clearly superior to those of other materials in the series. Oenanthic ether gave an average trap-day return of 2 moths, in comparison with 1.7 moths for anisaldehyde, considering the two locations separately. Oenanthic ether is a term used to designate a mixture of ethyl esters derived from the lower fatty acids found in coconut oil. The material used in these trials was composed primarily of ethyl laurate with some lower-boiling material present.

In a subsequent trial in 1948, the ethyl esters of 11 aliphatic acids were compared with anisaldehyde and oenanthic ether as standards, as shown in Series A, table 3. Among the esters series only ethyl palmitate proved to be very attractive, there being an unusually high proportion of females to males in the catch (6:1). The generally encountered attractiveness of oenanthic ether to moths is thus probably related to a mixture of odors rather than to the odor of any one component. Anisaldehyde caught the largest number of moths, with a ratio of females to males of 3:1.

The five replicates of each of the three best attractants in this series were renewed on July 15 and run until August 31, along with five water checks, all with addition of water, only, once a week. Moths were flying in small numbers during this trial. Ethyl palmitate caught 5 females only, 2 of these during the sixth week after installation. Anisaldehyde caught 6 males, 1 in the seventh week, and 11 females, 3 in the sixth week after installation. This indicates a relatively long period of attractiveness for these materials. Oenanthic ether caught 2 males, only, during the fourth week, and none were caught in the water checks.

In a separately replicated trial simultaneous with that of Series A, table 3, aldehydes and alcohols related to anisaldehyde and other potential attractants were tested, as shown in Series B, table 3. Since the skeletonizer is found almost exclusively on grapevines, compounds oc-

Table 2.—**Trial of potential attractants for moths of the western grape leaf skeletonizer in two series in different locations, 1947.**

MATERIAL[1]	TOTAL MOTHS TRAPPED	
	Series A[2] (Bostonia), July 23 to Aug. 11	Series B[3] (Los Coches Creek), July 29 to Aug. 29
Anisaldehyde	12	372
Oenanthic ether[4]	55	306
Oil of star anise (U. S. P.)	7	92
Terpineol	3	74
Oil of orange (U. S. P., Sweet American)[4]	1	32
Oil bergamot (N. F.)[4]	4	21
Oil of lemon (U. S. P. XII, Californian)[4]	2	15
Citral	2	13
Water only	3	4
Anisaldehyde in vial suspended in water	0	—

[1] Formulated as follows: 33.3 cc. attractant, 66.6 cc. water, 1 gram bentonite.
[2] Actual attractant per trap on July 23, 2.5 cc.; two replicates randomly placed in close proximity to grapevines; traps rotated every 5 days.
[3] Actual attractant per trap on July 29 and Aug. 13, 3 cc.; replicates randomly placed in four blocks; traps not rotated.
[4] Fisher Scientific Co.

Table 3.—Results of trials with ethyl esters of aliphatic acids and with compounds related to anisaldehyde or methyl anthranilate as attractants for moths of the western grape leaf skeletonizer, Los Coches Creek, 1948.[1]

Material[2]	Number of Moths Trapped, June 16 to July 15		
	Male	Female	Total
Series A. Esters of Aliphatic Acids			
Anisaldehyde	23	68	91
Ethyl palmitate	3	19	22
Oenanthic ether[3]	3	2	5
Ethyl caproate[4]	3	0	3
Ethyl propionate	1	2	3
Ethyl *n*-heptylate	3	0	3
Ethyl *n*-caprate	2	1	3
Ethyl formate	1	1	2
Ethyl laurate	1	1	2
Ethyl *n*-butyrate	1	0	1
Ethyl *n*-caprylate	0	0	0
Ethyl *n*-valerate	0	0	0
Ethyl acetate	0	0	0
Water+3 drops Triton X-100	0	0	0
Water only	0	0	0
Series B. Compounds Related to Anisaldehyde or Methyl Anthranilate			
Methyl anthranilate	36	63	99
Anisaldehyde	4	13	17
Oenanthic ether[3]	6	10	16
o-Methoxybenzaldehyde	4	9	13
Benzaldehyde	2	5	7
Ethyl anisate	5	1	6
p-Methoxybenzyl alcohol	4	2	6
n-Heptyl alcohol	3	3	6
n-Heptaldehyde	1	4	5
Ethyl anthranilate	2	2	4
Methyl anisate[5]	1	0	1
Anthranilic acid[5]	0	0	0
Anisic acid[5]	0	0	0
Water only	0	0	0

[1] Replicated five times. Traps (pails) hung 6 to 8 feet from the ground and 6 to 8 feet apart on wires strung across infested creek bed area; rotated approximately every fourth day by advancing pails along the wire, replacing first pail in each block with the last. Water added every fourth day. Replicates of Series A alternated across creek bed with those of Series B, 50 to 75 feet apart.

[2] Attractants added to traps on June 16 and July 1. Unless otherwise noted, 3 cc. of actual attractant was added to each trap, from the following formulation: 30 cc. attractant, 68.5 cc. water, 1.5 cc. *Triton X-100*. All compounds Eastman white label (highest parity) unless otherwise noted.

[3] Fisher Scientific Co.; oenanthic ether and anisaldehyde included in each series as standards.

[4] Eastman blue label (technical).

[5] Solid materials were sprinkled on water in trap; 3 grams per trap.

curring naturally in the host were considered as potential attractants. Methyl anthranilate, a naturally occurring constituent of grapes, was therefore included in this series along with several related compounds. Methyl anthranilate caught almost six times as many moths as anisaldehyde or oenanthic ether, the next best materials, which were closely followed by *o*-methoxybenzaldehyde.

Most of the moths in the methyl anthranilate pails and in both series of anisaldehyde replicates were caught during the first 5 days after the two dates on which attractants were placed in the pails. The ratio of females to males caught by methyl anthranilate was 1.75:1.

The four best attractants in Series B, table 3, were renewed along with the water check on July 15 and were maintained until August 31. In addition, three essential oil components and anisole were replicated in with this series. Moths were present in low numbers during this period. Results presented in table 4 show that methyl anthranilate was apparently superior to the other materials. Examination of the records on a weekly basis shows that of the 5 males and 7 females in the methyl anthranilate traps, 1 male and 2 females were caught during the seventh week after attractant was supplied.

In 1948 two trials were conducted on the effect of the emulsifiers, bentonite and Triton X-100, on the performance of three attractant compounds: anisaldehyde, methyl anthranilate and oenanthic ether. There was no consistent trend in the results.

Because of the numerous uncontrolled factors in field experimentation with attractants, discussion of the basic attractant value of a given compound becomes largely a matter of speculation. Since, as shown below, male skeletonizer moths are attracted to the female by odor, trap catches of males may result to some extent from this factor, for moths initially float on the water and live for some time after being caught on the trap surface.

In six trials the average ratio of females to males attracted by methyl anthranilate was 1.6:1; with oenanthic ether the ratio was 1.4:1; and with anisaldehyde, 3:1. The fairly constant predominance of females caught in traps baited with the first two materials could be attributed to an ability of males to escape entrapment, but the greater predominance of females attracted by anisaldehyde indicates that this compound is indeed more attractive to females.

Table 4.—Comparisons among various potential attractants during a period of low populations of moths of the western grape leaf skeletonizer, Los Coches Creek, 1948.[1]

Material	Number of Moths Trapped, July 15 to Aug. 31		
	Male	Female	Total
Methyl anthranilate	5	7	12
d-Limonene[2]	2	1	3
Anisaldehyde	0	1	1
Anisole	1	0	1
Linalyl acetate[2]	0	1	1
Linalool[3]	—	—	1[4]
o-Methoxybenzaldehyde	1	0	1
Water only	—	—	1[4]

[1] Five replications installed July 15 with 3 cc. actual attractant per trap, emulsified with Triton X-100. Water added every 7 days. Moths present in low numbers during this period.
[2] Eastman blue label (technical).
[3] Eastman white label (highest purity).
[4] Sex not known.

Table 5.—Comparisons among attractants, alone and in combinations, for moths of the western grape leaf skeletonizer, Sweetwater River, Dehesa Valley, 1950.

Material	Actual Attractant per Trap[1] (cc.)	Number of Moths Trapped, Aug. 2–25		
		Male	Female	Total
Methyl anthranilate	3.0	8	9	17
Anisaldehyde	3.0	0	2	2
Oenanthic ether	3.0	5	6	11
Methyl anthranilate Anisaldehyde	1.5 1.5	2	6	8
Methyl anthranilate Oenanthic ether	1.5 1.5	5	16	21
Anisaldehyde Oenanthic ether	1.5 1.5	5	3	8
Methyl anthranilate Anisaldehyde Oenantic ether	1.0 1.0 1.0	6	16	22
Ethyl palmitate	3.0	7	20	27

[1] From the following formulation: total attractant, 30 cc.; bentonite, 1 gram; water, 70 cc.; at 10 cc. of formulation per trap. Five replications.

The unusually large predominance of females caught by ethyl palmitate strongly suggests an ovipositional-type attractant value for this compound. In the three trials with this compound, the average ratio of females to males trapped was 4.4:1. In contrast to anisaldehyde, oenanthic ether, and methyl anthranilate, which provided highest trap returns soon after trap installation, catches with ethyl palmitate were highest after 10 to 15 days. This suggests that palmitic acid, possibly present as a result of bacterial de-esterification, may be the true female attractant.

In a trial in 1950, reported in table 5, methyl anthranilate, anisaldehyde, and oenanthic ether were used alone and in varied combinations, the total amount of attractant per trap being the same in each case. The results of this trial suggest that combinations of attractants should be investigated further, since two of the combinations gave higher returns than the same materials alone. From these limited results it also appears that combinations of attractants may be somewhat more attractive to females than to males. Ethyl palmitate was tried for comparison with this series and gave the highest total catch.

TRIALS WITH FEMALE MOTH EXTRACTS, 1948–1950.—Studies with female moth extractives to attract male moths are reviewed by Roth & Willis (1952). Extracts of female moths have long been used in gypsy moth survey work (Burgess 1950). Terpinyl acetate infusions of male or female oriental fruit moths have been shown to increase total moth catch by Carman.[8] A trial with extracts of female western grape leaf skeletonizer moths was therefore carried out in 1948.

In this trial, female moths were extracted with methyl anthranilate. The sex ratio of moths caught with methyl anthranilate alone in this trial was 1.75 females to 1 male. With methyl anthranilate bearing extracts of one-half female moth per cubic centimeter, at the usual dosage of 3 cc. per trap, the sex predominance was reversed, the ratio becoming 1 female to 3.5 males, the actual number of females caught being but 13 per cent less. This suggested that a sex attractant soluble in methyl anthranilate caused the unusually high catch of males in this trial.

Preliminary trials with benzene extracts of female moths in 1950[9] demonstrated that males were readily attracted. Further trials with benzene extracts of female moths placed in various types of traps were therefore conducted for comparison with other types of attractants. Extracts of two female moths in 2 cc. of benzene were placed on a

[8] Carman, G. E. Report of studies during 1945 on the oriental fruit moth. Unpublished.
[9] By W. M. Pearce.

rolled strip of corrugated cardboard 1½ inches in width and 9 inches in length (Burgess 1950), suspended by a wire within each of the following kinds of traps: a Graham-type trap consisting of a metal tube 3½ inches in diameter and 8 inches long, equipped at each end with a screen cone having a hole at the apex for entrance of moths; the same without the screen cone; the cardboard cylinder from a 1-quart ice cream carton, with top and bottom removed; and a 1-quart milk carton with top and bottom removed. Tanglefoot was applied directly to the inside of the milk carton. The other traps were provided with liners of cardboard or Kraft paper on which tanglefoot had been spread to entrap the moths. In the same series, trials with methyl anthranilate, oenanthic ether, and anisaldehyde were replicated in water-filled fiberboard pails and in ice cream cartons, the attractant for the latter being placed on the rolled, corrugated cardboard cartridge and inserted as described above. One of each of the ten trap-attractant types was placed in each of five different areas in the vicinity of wild grapevines. Results are presented in table 6.

Results indicate that male skeletonizer moths may be readily lured with female extractives. Although sex could not be determined in every case, it is assumed that only male moths were caught in traps baited with the benzene extract of females, since no females were found. Daily records show that 77 per cent of these moths were caught in the first 24 hours and 18 per cent in the second 24 hours after the female extract was placed in the trap. Observations indicate that the limit of attractiveness was about 36 hours.

It will be noted that the trap totals in this trial for the three attractants other than the sex attractant are for a period of 7 to 12 days, which is considered to be a normal period for survey servicing. When these totals are compared with that of the sex-attractant traps, which had accumulated in 2 days, it will be noted that significantly larger total numbers of moths were caught in the sex-attractant traps than in traps baited with the three other attractants used.

The sex-attractant-type trap has the disadvantage of a short period of attraction because of relatively rapid volatilization or decomposition of the active principle. It may be possible to extend the period of attractiveness, however, by increasing the amount of extract per trap or by formulating this extract in a different manner. The sex-attractant-type trap would be quite useful in canyon areas where water is not available to maintain the fiberboard pail traps.

Table 6.—Female moth extract compared with other materials as attractants for moths of the western grape leaf skeletonizer, 1950.[1]

Attractant	Trap		Number of Moths Trapped			
	Type	Tanglefoot Liner	Male	Female	Sex undetermined[2]	Total
Extracts of 2 females[3]	Metal tube (no screen)	Cardboard	19	0	12	31
	Metal tube (screened)	Cardboard	14	0	2	16
	Milk carton	none	13	0	4	17
	Ice cream carton	Kraft paper	13	0	6	19
Methyl Anthranilate[4]	Ice cream carton	Kraft paper	0	0	5	5
	Water-filled fiber-board pail	—	3	4	0	7
Oenanthic ether	Ice cream carton	Kraft paper	0	0	4	4
	Water-filled fiber-board pail	—	3	4	0	7
Anisaldehyde	Ice cream carton	Kraft paper	0	0	4	4
	Water-filled fiber-board pail	—	0	3	0	3

[1] Replicated by placing one of each of the attractant-trap types in five localities. Exposed for 12 days in two localities and for 7 days in three localities. Trapped moths recorded daily. Moth population low.
[2] Moths thoroughly entrapped in tanglefoot; sex determination difficult.
[3] In benzene; 1 female per cubic centimeter.
[4] Emulsified with *Triton X-100*, as described in footnote 2, table 3, for use in fiberboard pail trap.

SUMMARY.—The attractant value of more than 50 materials for moths of the western grape leaf skeletonizer, *Harrisina brillians* B. & McD., in the field was evaluated in studies conducted during four seasons. These materials included fermenting baits, certain essential oils and essential oil components and related materials, ethyl esters of several aliphatic acids, a compound known to be present in grapes, and female moth extractives. For these trials water-filled fiberboard pails were used, except when moth extractives in benzene served as attractants. For the latter, modified Graham-type traps were used.

Under the conditions of these trials, of the materials other than the sex attractant, methyl anthranilate appeared to be the most attractive, followed by anisaldehyde and oenanthic ether. Ethyl palmitate displayed good attractive value for female moths. Catches with this material were highest 10 to 15 days after installation of traps; this suggests that a decomposition product may be the true attractant. A benzene extract of female moths proved to be highly attractive to male moths and provided much higher total trap returns than other attractants. This extract, used at the rate of two females per trap, ceased to be attractive to male moths after 36 to 48 hours. It may be possible to extend the period of attractiveness by increasing the amount per trap or varying the extract formulation.

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Culex pilosus (D&K) in Texas

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Routine mosquito collections carried on by the various military installations throughout the Fourth Army Area have resulted in the establishment of a new mosquito record from Texas. Personnel of the Surgeon's Office, Longhorn Ordnance Works, Marshall, Texas, on 23 August 1950, collected three larvae of *Culex pilosus* (D & K) from a ditch. Attempts were made to obtain adult specimens but these were unsuccessful. A search of the literature shows that this species has been reported from Alabama, Florida, Georgia, Kentucky, Louisiana Mississippi, North and South Carolina; therefore, the occurrence in Texas is not surprising. The larvae typically occur in temporary waters, ditches, pools, and floodwaters. The eggs are reported to withstand considerable drying. Little is known of the feeding habits of the adults. The identification of these specimens was confirmed by Dr. Alan Stone of the U. S. National Museum. Two of the specimens are deposited in the U. S. National Museum, Catalog Number 16756; the remaining one is retained in the collection of the Fourth Army Area Medical Laboratory, Brooke Army Medical Center, Fort Sam Houston, Texas.

Metabolism of Schradan by Plants and Insects to a Toxic Phosphoramide Oxide[1]

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The efficient and safe use of systemic insecticides depends in part on a thorough knowledge of their mode of toxic action to insects, plants and mammals. Where active metabolites are formed, their chemical nature and toxicity should be determined.

This study was concerned with the systemic insecticide schradan (octamethylpyrophosphoramide). Investigation was directed towards identification of that plant metabolite of schradan which exerts an anticholinesterase effect and the development of analytical methods for evaluating the residues of schradan and its active metabolites in plants. The mode of toxic action to insects was also studied, particularly in relation to the specific biochemical differences between insects, plants and mammals that allow schradan to function as a systemic insecticide.

Methods.—Cholinesterase activity was determined according to the modified method described by Casida *et al.* (1952c). An aliquot of the anticholinesterase agent in an organic solvent was pipetted into a Warburg vessel and the solvent was removed by evaporation. The inhibitor was then incubated with the tissue homogenates for 60 minutes at 37° C. prior to addition of the substrate.

The enzyme chymotrypsin has certain advantages for organophosphate studies over cholinesterase; these include availability, chemical homogeneity, stability, and the availability of information concerning the nature and stoichiometry of the chemical reaction involved (Casida *et al.* 1952b). This enzyme was assayed manometrically with L-tyrosine ethyl ester as the substrate at 0.25 molar concentration in a solution containing 0.021 molar sodium bicarbonate and 1.15 per cent potassium chloride. This substrate solution was adjusted to pH 6.25 and could be kept about 3 days with refrigeration (or as long as the solution remained clear). A stock enzyme solution was prepared containing 30 micrograms of enzyme protein[3] per ml. dissolved in a buffer of M/50 potassium phosphate adjusted to pH 6.25. Refrigeration preserved the enzymatic activity for several days. A known aliquot of the inhibitor in a volatile organic solvent was placed in a test tube, the solvent evaporated off and 1.5 ml. of the enzyme solution added to the tube and mixed. The inhibitor and chymotrypsin were incubated together overnight at 4° C. prior to assay.

The manometric chymotrypsin assay was accomplished by adding 0.20 ml. of the substrate solution to the side arm of the flask, then 1.0 ml. of the enzyme-inhibitor solution from the test tube and finally 0.80 ml. of a 0.4 per cent solution of sodium bicarbonate to the vessel. The flasks were gassed with carbon dioxide for 10 minutes, and equilibrated in a 37° C. water bath for 10 minutes prior to tipping in the substrate. Carbon dioxide evolution was measured over a period of 40 minutes, the readings of the first 10-minute period being discarded because of their greater variability. Comparisons were made of the carbon dioxide evolution from inhibited enzyme compared with a control enzyme solution. A linear relationship existed between per cent inhibition and the logarithm of the inhibitor concentration.

Formaldehyde was determined using a modified chromotropic acid method of Krueger (1949). A test tube containing 2.0 ml. of the formaldehyde-yielding material in aqueous solution was chilled in an ice bath and 2.0 ml. of concentrated sulphuric acid (A.R.) was added dropwise from a burette. Then 0.2 ml. of 7 per cent chromotropic acid was added and mixed with the tube contents and the color developed by placing the tube in a boiling water bath for 30 minutes. After color development, the tubes were cooled and

[1] Approved for publication by the director of the Wisconsin Agricultural Experiment Station. This investigation was supported in part by the Research Committee of the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation. We gratefully acknowledge the skilled technical assistance of W. B. Rathbun, G. T. Bryan and R. E. Shenefelt.
[2] Presented Dec. 18, 1952 at the meeting of the American Association of Economic Entomologists in Philadelphia, Pa.
[3] Crystalline enzyme, Armour Co. or Worthington Biochemical.

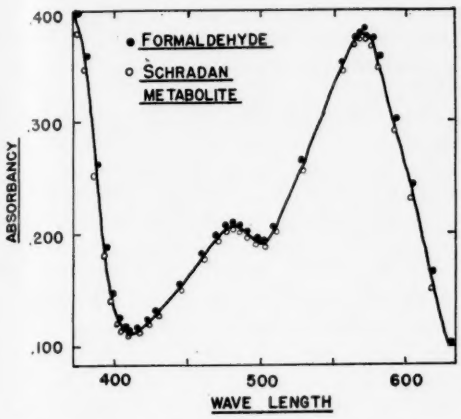


FIG. 1.—Wave length-absorption curve for schradan metabolite compared with pure formaldehyde. (Schradan metabolite curve was obtained by distillation of acid hydrolysate prior to addition of chromotropic acid. Metabolite was purified from tomato plants by countercurrent distribution with methylene chloride and water.)

read at 570 mμ. Figure 1 shows a wave length-absorption curve for the schradan metabolite from plants compared to pure formaldehyde by this method. Where interfering materials were present in the biological tissue, a distillation of the formaldehyde was employed. For this purpose 3.0 ml. of water containing the formaldehyde-yielding material were placed in a small pear-shaped flask for use with a 16 cm. condenser. Immediately prior to distillation 1.0 ml. of concentrated hydrochloric acid was added and the flask rapidly attached to the condenser and lowered into an oil bath at 200° C. Glass beads were used to prevent bumping and a small glass wool plug was inserted into the condenser inlet as a spray trap. The distillate was collected in a test tube cooled in an ice bath and the distillation allowed to proceed to dryness. To the cooled distillate was then added dropwise 4.0 ml. of concentrated sulphuric acid and 0.2 ml. of chromotropic acid solution and the color developed and read as indicated above. Trioxymethylene was used as a standard.

Other Methods.—The schradan employed was prepared from a technical commerical product[4] purified by fractional distillation and alkaline hydrolysis (Hartley *et al.* 1951) to yield a product distilling over a range of 134.5° to 135.0° C. at 1.0 mm. The chemical nature, stability, partitioning characteristics and physiological activity of the various components of the commercial schradan have been studied in detail (Hartley *et al.* 1951). The study reported here concerns only one chemical from this complex commercial preparation, the primary insecticidal material and the component responsible for the majority of the mammalian toxicity, octamethylpyrophosphoramide.

Other methods employed were countercurrent distribution analysis (Craig & Craig 1950), manometric techniques (Umbreit *et al.* 1949) and phosphatase enzyme assays (Casida *et al.* 1952c). All tissue homogenates were prepared with a Potter-Elvehjem glass homogenizer (Potter & Elvehjem 1936).

SCHRADAN METABOLISM IN PLANTS.—Schradan is metabolized by plants to form an anticholinesterase agent. This metabolite can be readily detected by enzymatic assays (DuBois *et al.* 1950, Hall *et al.* 1951, Casida *et al.* 1952c and, Metcalf & March 1952), but is not evident to mosquito larvae bioassay (Zeid & Cutkomp 1951). A non-toxic analog of schradan, orthophosphoric acid tridimethylamide, decomposes at the same rate as schradan in plants (Hartley & Heath 1951). An oxidative breakdown has been suggested for this triamide with a methyl hydroxymethylamide as an intermediate (Heath *et al.* 1952b). Little chemical evidence is available on schradan decomposition in plants. Certain metabolites present in very low concentrations including the anticholinesterase agent (Hall *et al.* 1951) are soluble in chloroform (Hartley & Heath 1951, Heath *et al.* 1952a). Some decomposition products can be precipitated by calcium salts in alkaline solutions (Hartley & Heath 1951). Various mechanisms which have been postulated for schradan metabolism in plants include a biological oxidation of a methyl group (Hartley 1951)[5] or the amide nitrogen (Heath *et al.* 1952b), or the formation of a hydroxymethyl derivative (Heath *et al.* 1952b).

Hartley[5] in England and the Food and Drug Administration of the United States Federal Security Agency (Lehman 1952) have been firm in their conviction that a full investigation of the decomposition of

[4] Monsanto Chemical Co. 70 per cent octamethylpyrophosphoramide.

[5] Hartley, G. S. 1951. First steps in the biochemistry of systemic insecticides. Address before XIIth, International Congress of Pure and Applied Chemistry. New York, Sept. 10–13.

schradan in the plant is essential to the safety of the consumer (Casida & Allen 1952a).

Chemical Identity.—The recent characterization of the toxic metabolite of schradan in mammals (Casida *et al.* 1953)[6] and the general similar metabolic functioning of plants and animals suggested that possibly the plant metabolite might be this same phosphoramide oxide. Accordingly a group of schradan-treated tomato plants were macerated in water, extracted with chloroform and the chloroform extract fractionated by a countercurrent distribution technique (Craig & Craig 1950). This fractionation was done in an identical manner and produced identical results as have been reported with the mammalian metabolite of schradan (Casida *et al.* 1953).[6] A material which yielded formaldehyde on treatment with acid could not be separated from the active anticholinesterase agent. Figure 1 shows a transmittance-wave length curve obtained with a standard formaldehyde solution as compared to a curve obtained with this metabolite containing extract of tomato plants. The formaldehyde-yielding material possessed a greater affinity for water than did schradan itself and inhibited cholinesterase in the same concentration range as did the mammalian metabolite. The identify of these biological oxidation products in plants and mammals is evident from the data shown in table 1. These results are based on the amount of formaldehyde-yielding material

Table 1.—Identity of schradan metabolite from plants and mammals.

	PLANT[1]	MAMMAL[2]	SCHRADAN
Partition Coefficient:[3]			
$CH_2Cl_2H_2O$	0.63	0.65	2.0
$CH\ Cl_3/H_2O$	1.68	1.58	6.8
$C\ Cl_4/H_2O$	0.22	0.22	0.004
Molar Conc. 50% ChE inhibition:[4]	3.5×10^{-7}	3.3×10^{-7}	1.5×10^{-1}

[1] Metabolite from young schradan-treated spinach plants—the metabolite was purified by chloroform extraction and countercurrent distribution with CH_2Cl_2 and H_2O.
[2] Metabolite from rat liver slices according to Casida *et al.* (1953).[6]
[3] Ratio based on material yielding formaldehyde on treatment with acid.
[4] Molar concentration based on formaldehyde analysis; rat brain homogenates were used as source of cholinesterase.

partitioning between the two phases and show that the metabolite from mammals and plants partition in the same manner with all three solvent systems. These observations—countercurrent distribution data, solvent partitioning characteristics and enzymatic inhibitor assays—are strong evidence that the metabolite from mammalian livers and plants are the same substance. The cholinesterase inhibitor formed from schradan in plants therefore appears to be the *monophosphoramide oxide of octamethylpyrophosphoramide.*

Methods for Residue Analysis.—It is essential that an adequate method be available for analysis of schradan-treated plants for the residual metabolite which might be toxic to mammals. Bioassay with mosquito larvae, houseflies, fruit flies and cockroaches was not sufficiently sensitive. Bioassay methods where the chemical was taken up by a plant and then tested with sucking insects have been found satisfactory (David & Kilby 1949, Wallace 1951).

Two possible methods of chemical analyses are evident; the sensitive enzymatic analysis (Giang & Hall 1951), or a specific chemical group analysis. With the schradan metabolite, cholinesterase is sensitive to about 0.0002 micromoles or 0.06 micrograms in the plant sample, while chymotrypsin is sensitive to about 0.005 micromoles or 1.5 micrograms of schradan metabolite. Since the metabolite is a mono and phosphoramide oxide, it will yield one mole of formaldehyde on treatment with acid for each mole of metabolite present. Formaldehyde analysis as outlined under methods is sensitive to less than 0.05 micromoles (15 micrograms), and if few interfering materials are present the sensitivity may approach 5 micrograms of schradan metabolite. The relative sensitivity of these methods is illustrated by the standard curves shown in Figure 2.

It is not possible at the present time to propose a standard residue analysis procedure for the schradan metabolite because of the variation in the interfering materials that are encountered. Homogenates of treated plants may be added directly to the enzyme to give an indication of the amount of inhibitor present (Casida *et al.* 1952c). The plant may be homogenized in an aqueous buffer (1 molar phosphate buffer at pH 7.0), extracted with chloroform and the organic phase analyzed. Further purification may be achieved by first extracting the buf-

[6] Casida, J. E., T. C. Allen and M. A. Stahmann. 1953. Metabolic conversion of octamethylpyrophosphoramide to a toxic phosphoramide oxide. (Unpublished.)

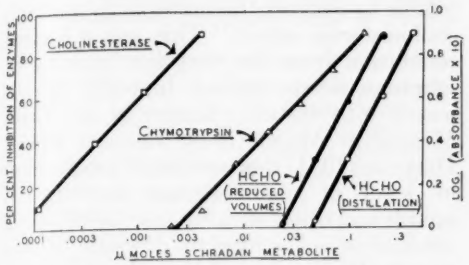


FIG. 2.—Sensitivity of various analysis methods for schradan metabolite. (Metabolite was obtained from rat liver slices. Analysis methods as described in text.)

fered aqueous solution with carbon tetrachloride to remove interfering materials and then with chloroform to remove the schradan metabolite. A countercurrent distribution technique permits further purification. The accuracy and sensitivity of these methods was determined by adding known amounts of schradan metabolite (obtained from plants or liver tissue) to homogenates from similar untreated plant material for recovery analyses. A sample of the metabolite for recovery studies can be prepared with rat liver slices or with permanganate (Casida *et al.* 1953)[7] and the concentration standardized by formaldehyde analysis (see methods).

Tomato plants 4 to 5 inches in height growing in schradan-treated soil for 9 days contained 18 p.p.m. of schradan and 2.5 p.p.m. of the phosphoramide oxide metabolite (based on formaldehyde analysis). In this case the metabolite consisted of 12.2 per cent of the chloroform extractable phosphorus-containing material. With older plants this content of metabolite was 1.2 per cent of the phosphorus materials for peas, 0.8 per cent for cabbage and even less for corn and onions. When treated under identical conditions there was a residue of schradan in the plant after 1 week at 63 p.p.m. for pole beans, 50 p.p.m. for cabbage, 34 for cucumber, 76 for onion, 85 for peas, 36 for potatoes and 124 for young 6-inch corn plants and 47 p.p.m. for tasseled corn. There was a greater variability in the occurrence of the metabolite than of schradan among these plants and the metabolite concentration was probably near a maximum because of the rapid plant growth and the short term experiment.

To evaluate the possible health hazard of plants treated with schradan it would appear desirable to analyze these plants for both schradan and its metabolite. The procedure of Hall *et al.* (1951) essentially measures the total of these since it determines the dimethylamine-containing materials in a chloroform extract of the plant. A good specific method for schradan is the phosphorus residue analysis of David *et al.* (1951) in which the alkaline hydrolysis step would destroy the unstable phosphoramide oxide. A combination method for treated plants utilizing the phosphorus method of David *et al.* (1951) for schradan and the formaldehyde method or an enzymatic assay for the metabolite would appear most desirable.

Phosphatase Activity and Phytotoxicity.—The phytotoxicity of schradan may also be associated with this phosphoramide oxide metabolite. In one case a direct relation has been demonstrated between the amount of schradan in the plant, the inactivation of the leaf phosphatase enzymes and the phytotoxicity of the insecticide (Casida *et al.* 1952c). Extracellular root phosphatase was also inhibited by an incubation with schradan and it was pointed out that this was due to some metabolite of schradan other than orthophosphate (Casida *et al.* 1952c). Tests under identical conditions have now shown that the excised roots can metabolize schradan to its phosphoramide oxide which could in turn inhibit the phosphatase. A partial explanation of the phytotoxicity of schradan may therefore be found in its conversion to the phosphoramide oxide which then inhibits phosphatase or other essential esteratic plant enzymes.

TOXICITY OF SCHRADAN-TREATED PLANTS TO MAMMALS.—Ripper *et al.* (1950) conducted extensive feeding experiments with schradan-treated plants and noted no toxic effects in any case. Experiments of David *et al.* (1951) demonstrated that the schradan decomposition products which do not readily extract into chloroform do not offer a serious health hazard.

The results presented here allow a more complete evaluation of the health hazards involved. After absorption by plants, schradan has a biological half life of about

[7] Casida, J. E., R. K. Chapman, T. C. Allen, and M. A. Stahmann. 1953. Chemical oxidation of octamethylpyrophosphoramide in relation to its biological properties. (Unpublished.)

2 weeks (Hartley 1951[5] Heath *et al.* 1952a). The first intermediate in the metabolism appears to be the toxic, unstable monophosphoramide oxide of schradan. This oxidation product is the most effective cholinesterase inhibitor that appears in the oxidative degradation scheme for schradan (Casida *et al.* 1953).[7] The stability of the schradan metabolite is very much dependent on pH (Casida *et al.* 1953)[6] such that its half life in a plant might be a few hours to 2 or 3 days. But the plant is always converting more schradan so there is always a certain amount present in the plant. When an animal consumes the plant it takes up both schradan and phosphoramide oxide. The schradan is readily absorbed from the gastro-intestinal tract (DuBois *et al.* 1950) but a large proportion of the metabolite might be lost prior to absorption because of its instability. The animal then rapidly produces this same phosphoramide oxide metabolite. Oxidation of schradan with permanganate (Casida *et al.* 1952b, 1953[7]) also yields as its initial product the same anticholinesterase agent that is formed by plants or mammals (Casida *et al.* 1953). Oxidation mixtures contained from about 0.5 to 5 per cent of the active phosphoramide oxide with schradan comprising the other major portion, a synthetic mixture very similar to that found in treated plants. Where injected intraperitoneally into white rats, no difference could be detected in the toxicity of schradan and the various oxidation mixtures tested, the LD_{50} being about 8 mgm./kg. It should be pointed out that certain other phosphoramides were definitely increased in their mammalian toxicity by a similar oxidation. Since the drastic pH changes and delay in absorption encountered in the gastro-intestinal tract were avoided, the schradan metabolite should have displayed its maximum toxic manifestations under these test conditions. The mammalian body can apparently convert schradan to its active metabolite at a sufficient rate that the presence of up to 5 per cent of the phosphoramide oxide initially will not greatly increase the toxic hazards. It would thus appear that the anticholinesterase agent formed in the plant does not offer a serious health hazard.

METABOLISM OF SCHRADAN IN INSECTS. From his studies on schradan, DuBois *et al.* (1950) considered that "insects are unable to convert the material to an anticholinesterase agent." This was a logical conclusion from the very low toxicity of schradan when applied topically or injected into insects (Ripper *et al.* 1949, Metcalf & March 1949, Bennett 1949). Duspiva (1951) demonstrated a reduction in level of cholinesterase activity of aphids and other sucking insects following application of schradan directly to the insects. He considered that the resistance of certain insects to the toxic action of schradan was due to a lack of the enzyme system capable of forming the active inhibitor of cholinesterase. Metcalf (1952)[8] has shown that the isolated digestive tract of the cockroach, which is very resistant to schradan, readily converts the phosphoramide to an anticholinesterase agent.

The identity of the toxic schradan metabolite in insects was established in the same manner as the plant metabolite. It was found to be identical with the metabolite from mammals and plants in regard to activity as an anticholinesterase agent, chymotrypsin inhibition, formaldehyde liberation, partitioning properties and stability. Thus insects also converted schradan to the toxic phosphoramide oxide.

The digestive system of the American cockroach, *Periplaneta americana* (L.), was subdivided to determine the site of schradan metabolism. Gas exchange was also determined for the tissues since a direct relationship has been indicated between the efficiency of schradan metabolism and the oxygen requirement of the tissue (DuBois *et al.* 1950, Hartley 1951[5]). As shown in table 2, the greatest metabolite formation occurred with the gastric caecae and malphigian tubules and appeared to be more directly related to the normal secretory functions than to the excess of oxygen uptake over carbon dioxide evolution.

Three possible biochemical mechanisms were considered to explain differences in the susceptibility of insects to schradan; ability to form the metabolite, ability to detoxify the metabolite, and the sensitivity of the cholinesterase of the insect to this metabolite. As shown in table 3, the suggestion by Duspiva (1951) that insects which are resistant to schradan do not contain the enzyme system

[8] Personal communication.

Table 2.—**Metabolism of schradan by tissues from the isolated alimentary canal of *Periplaneta americana* (L.).**

ORGAN	RELATIVE RATES/MGM. DRIED TISSUE	
	Gas Exchange[1]	Metabolite Formation[2]
gastric caecae	41	100
malpighian tubules	47	81
salivary glands	100	57
esophagus	57	48
rectum	35	47
proventriculus	−1	31
ventriculus	2	29
crop	−28	16
colon	23	10

[1] Pure oxygen atmosphere, 38° C.; rate based on microliters per hour per mgm. dry weight tissue.

[2] Determined from chloroform extract of supernatant buffer following 5 hours incubation in Kreb's ringer phosphate buffer at pH 6.5 with M/1 schradan; rate based on micromoles acid-liberatable HCHO per hour per mgm. dry weight tissue.

necessary to form this metabolite does not appear to be applicable, although relative activity differences in this system may well be a contributing factor. Neither does a rapid detoxification mechanism appear to be the explanation since large amounts of the metabolite could be recovered from resistant insects which showed none of the symptoms characteristic of an anticholinesterase agent in insects (Chadwick & Hill 1947). The last possibility considered is based on the finding of Metcalf & March (1950) that biochemical specificity in the *in vitro* inhibition of cholinesterase by organophosphates is well correlated with the specificity of these chemicals as *in vivo* toxicants. Where the chemical displays no specificity in its toxic action the LD_{50} and concentration of 50 per cent cholinesterase inhibition *in vitro* do not vary with insect species. This relationship holds except where an *in vivo* conversion is involved (Holmstedt 1951). To see if the effectiveness of the schradan metabolite *in vitro* varied with the source of the enzyme, an active metabolite preparation from rat liver slices was tested against different sources of insect cholinesterase of approximately the same total measured activity. It is particularly interesting to note, table 3, that those insects resistant to topical application of schradan were also those whose cholinesterase was most resistant to the schradan metabolite. This evidence is very preliminary in nature but indicates that a specificity in action of the schradan metabolite against different sources of insect cholinesterase is a factor involved in the resistance of certain insects to schradan.

Table 3.—**Selectivity of schradan metabolite in different animals.**

	PHOSPHORAMIDE OXIDE FORMATION	SENSITIVITY OF ChE TO PHOSPHORAMIDE OXIDE[3]
Killed by topical application[1]		
white rat	+	100
pea aphid—*Macrosiphum pisi* (Kltb.)	+	?
house fly—*Musca domestica* L.	+	48
Not killed by topical application[2]		
German cockroach—*Blattella germanica* (L.)	+	8.0
Greenhouse whitefly—*Trialeurodes vaporariorum* (Westw.)	?	2.0

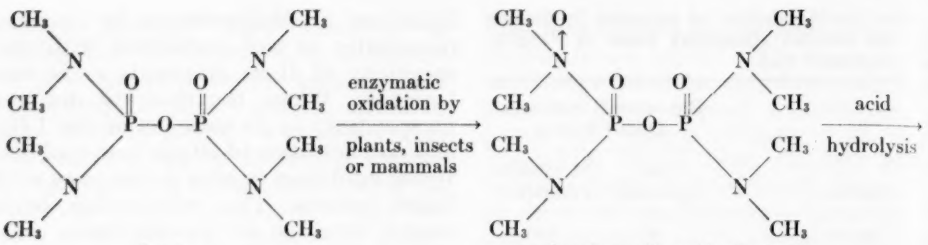
[1] Purified schradan diluted 1:50 in water and sprayed on animal to point of run off. First group of animals were dead in 2 hours while second group were still alive after 24 hours.

[2] Animals were sacrificed after 6 hours and attempts were made to identify the phosphoramide oxide in chloroform extracts by formaldehyde analysis. The whole insect was analyzed but only the liver from the rats. Whiteflies were not determined because of limited numbers.

[3] Enzyme sources were adjusted to same total activity level of 90 microliters of CO_2 evolution per 30 minutes by utilizing homogenates of 0.1 gm. rat brain, 5 roach heads, 200 whole whiteflies or 2.5 fly heads per 2 ml. in Warburg flask. Homogenates of whole aphids were inactive on acetyl choline. The active phosphoramide oxide used was obtained from metabolism by rat livers. Figures represent relative susceptibility of ChE to metabolite with 100 representing 50% inhibition at 3.5×10^{-7} M. and 2.0 this degree of inhibition at 7×10^{-6} M.

MODE OF INSECTICIDAL ACTION OF SCHRADAN-TREATED PLANTS.—Schradan is selective to different insects on the same plant and the same insect on different plants (Ripper *et al.* 1949, 1950). DuBois *et al.* (1950) concluded that "it is the active anticholinesterase agent produced within the plant which is responsible for the toxicity to insects." The work of Duspiva (1951) indicates that the insect forms its own toxic agent. The necessary concentration of schradan in plants to be lethal to insects has been variously estimated as 20 to 1000 micrograms per gram of tissue (David & Kilby 1949, David 1950 and 1951, Metcalf & March 1952). Hall *et al.* (1951) found a general correlation between the dimethylamide-containing material in chloroform extracts of treated plants and the insect mortality. Casida *et al.* (1952c) showed a correlation for the amount of schradan, the amount of metabolite and the insecticidal toxicity with pea plants. Davich & Apple[9] found that schradan in the plant gave a better correlation with pea aphid kill when determined by the phosphorus than by the dimethylamine analysis method. No data is available on the content of the phos-

[9] Paper entitled, "Translocation and persistence of schradan in the pea plant following soil and foliage application," presented at the meeting of the American Association of Economic Entomologists in Philadelphia, Pa., December 17, 1952.



schradan

monophosphoramide oxide of schradan
(anticholinesterase agent)

$$HCHO+CH_3NH_2\cdot HCl+3(CH_3)_2NH\cdot HCl+2H_3PO_4$$

FIG. 3. Chemical reactions involved in schradan metabolism.

phoramide oxide of schradan and insect kill.

Evidence in this paper indicates that the phosphoramide oxide of schradan is formed in both plants and insects so that either organism may be the effective site of conversion to the toxic agent. Even though less drastic pH changes are involved with the ingestion and absorption by insects than with most mammals, the low rate of conversion in the plant makes it probable that the insect metabolism contributes the greater part of the toxicant.

The limiting factor in the toxicity of schradan-treated plants appears to be the ability of the plant or insect to metabolize this precursor. This was demonstrated by comparing the systemic toxicity of schradan and partially oxidized samples (method of oxidation outlined previously) on pea aphids after uptake by pea plants from the soil. Chemical analysis based on dimethylamine showed that the oxidized samples were absorbed to the same extent as the non-oxidized. But the oxidized samples displayed a greater toxicity in the first five days after treatment than the non-oxidized. This toxicity difference with oxidation was even more pronounced with a schradan analog, bis(dimethylamino)p-nitrophenyl phosphate, and again was not due to differences in the absorption process. Field tests with foliage applications supported these findings.

SUMMARY.—Schradan is metabolized in plants to produce the toxic monophosphoramide oxide of octamethylpyrophosphoramide.

Methods of analysis for this phosphoramide oxide metabolite are presented. Three methods with varying degrees of sensitivity are described based on enzymatic inhibition of cholinesterase or chymotrypsin and colorimetric analysis based on formaldehyde liberated on degradation. The chemical reactions involved in the metabolism and colorimetric analysis are shown as figure 3.

The health hazard of this metabolite in plants was experimentally evaluated and shown to be relatively less significant than the residual schradan itself since:

a) The initial degradation product is the most toxic.
b) It is unstable and easily destroyed.
c) Its presence is directly dependent on a reservoir of the precursor, schradan.
d) Schradan is rapidly converted in mammals to this same metabolite slowly formed in low concentrations in plants.

Insects metabolize schradan through the same initial phosphoramide oxide step as do plants and mammals. The selective toxicity of schradan to certain insects is due to several causes including variation in their ability to metabolize schradan and differences in sensitivity of the insect cholinesterase to this anticholinesterase agent. The tissues found most active in metabolizing schradan are the gastric caecae of *Periplaneta americana* (L.). The toxic effect on insects would appear to be a resultant of the oxidation in the plant and in the insects.

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Tests with Pyrethrum Synergists Combined with Some Organic Phosphorus Compounds Against DDT-Resistant Flies

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For several years numerous investigators have been searching for compounds that would increase the effectiveness of insecticides against various species of insects. Most of the compounds that have increased the effectiveness of toxicants are nontoxic, or only slightly toxic, when used by themselves.

Eagleson (1940) demonstrated that sesame oil was synergistic with pyrethrum. Schroeder *et al.* (1948) tested 30 compounds containing the methylenedioxyphenyl group as synergists for pyrethrum against the house fly and mosquitoes and found several of them to be synergistic. Bushland & Eddy (1944) and Carson & Eddy (1949) evaluated several hundred materials as synergists for pyrethrum against the body louse; they found N-isobutylundecylenamide to be outstanding in effectiveness.

Sumerford (1951) found DMC (4,4-dichloro-alpha-methyl benzhydrol) to be a synergist for DDT against resistant house flies. March *et al.* (1952) found bis(*p*-chlorophenyl)chloromethane and 1,1-bis(*p*-chlorophenyl)-ethane to be synergists for DDT when used on resistant house flies.

Eddy *et al.* (1954) demonstrated that the insecticidal activity of certain organic phosphorus compounds against the body louse is greatly increased when they are used in combination with certain pyrethrum synergists. The synergistic action in this case was against body lice nonresistant to DDT. These studies prompted the writers to conduct exploratory work at Corvallis, Oreg., on the evaluation of known pyrethrum synergists in combination with certain organic phosphorus compounds against DDT-resistant house flies. Only a few of the many available organic phosphorus compounds were used. The synergists included a few commercial compounds known to synergize pyrethrum, several compounds synergistic with pyrethrum that have been recently synthesized by W. F. Barthel in the Bureau of Entomology and Plant Quarantine, and some that have shown promise in laboratory tests conducted at Corvallis.

MATERIALS AND METHODS.—The following organic phosphorus compounds were tested:

Malathion
EPN
Methyl parathion
Bayer compound 21/199 (3-chloro-4-methylumbelliferone 0,0-diethyl thiophosphate)
Bayer compound 21/200 (3-chloro-4-methylumbelliferone 0,0-dimethyl thiophosphate)
Potasan (4-methylumbelliferone 0,0-diethyl thiophosphate)
Diazinon (0,0-diethyl 0-(2-isopropyl-4-methyl-6-pyrimidyl) ester of thiophosphoric acid)

The candidate synergists are listed in table 1.

All tests were conducted by exposing DDT-resistant house flies (*Musca domestica* L., Orlando strain) to residues of the chemicals in widemouthed quart glass jars for 10 minutes.

The jars were treated by introducing measured amounts of acetone solutions of the organic phosphorus compounds, with and without synergists, and then rotating them until the acetone had evaporated. After 2 hours the flies were exposed to the residues. For each new test the jars were cleaned and retreated except where the persistence of the residue was studied.

After exposure the flies were removed to paper cartons and held for 24-hour mortality readings. Counts were made separately for each sex. The results are presented in this paper for females only, although in all tests the mortality of males was at least equally as high. The flies were 4 to 8 days old when used, and the tests were conducted at room temperature (70° to 75° F.). Approximately 30 female flies were used for each test, and an entire series was compared on the same stock of flies.

In order to determine whether synergistic action was produced, a rate of application of the toxicant alone was used that caused a low 24-hour mortality of flies exposed for 10 minutes. This rate varied with the toxicant used. A mortality of

Table 1.—**Per cent mortality of resistant house flies 24 hours after a 10-minute exposure to residues of organic phosphorus compounds alone and in combination with the candidate synergists. 2 to 5 replications.**

No.	Candidate Synergist	Malathion 5:25[1]	EPN 1:10	Methyl Parathion 1:10	Compound 21/199 5:25	Compound 21/200 5:25	Potasan 5:25	Diazinon 1:10
	None	3	22	51	20	4	18	23
1	N-Isobutylundecylenamide	70	98	97	87	6	100	75
2	Chrysanthemumic acid, alpha-propyl piperonyl ester	7	73	89	100	86	100	81
3	Chrysanthemumic acid, alpha-ethyl piperonyl ester	7	90	84	100	64	100	59
4	Chrysanthemumic acid, apha-isopropyl-piperonyl ester	9	54	84	87	31	90	77
5	*m*-Dioxane, 5-butyl-5-ethyl-2-(3,4-methylenedioxyphenyl)	16	79	82	100	75	100	68
6	Piperonyl cyclonene	0	2	16	64	10	0	13
7	Sulfoxide	0	58	87	97	86	94	94
8	Piperonyl butoxide	4	99	98 (0.5:5)	100	97	100	96
9	*n*-Propyl isome	0	6	3	76	36	30	32
10	Piperonylidenemalonic acid, diethyl ester	3	53	58	80	49	71	—
11	Hexahydrophthalic acid, di-*n*-butyl ester	78	90	87	75	40	100	72
12	Phthalic acid, methyl-*n*-hexyl ester	56	96	97	98	70	90	—
13	N,N-Diamylsuccinamic acid, propyl ester	35	90	95	82	57	88	—
14	N,N-Dipropyl succinamic acid, ethyl ester	67	99	68	88	26	88	—
15	N,N-Diethylsuccinamic acid	19	18	27	45	0	53	—
16	N,N-Di-isopropyl succinamic acid, ethyl ester	32	98	76	80	11	93	—
17	N,N-Diethyl glutaramic acid, ethyl ester	83	80	67	78	63	97	—
18	N,N-Dipropyl glutaramic acid, methyl ester	65	97	95	93	69	82	—
19	N-(2-Ethylhexyl)bicyclo-heptenedicarboximide	33	92	88	88	67	89	—

[1] The ratios in the column headings indicate the ratio of toxicant to synergist in milligrams per square foot.

less than 25 per cent was obtained with all toxicants alone except methyl parathion, where the mortality was 51 per cent.

When the toxicant was combined with a synergist, the dosage of toxicant was the same as that used to establish its toxicity when used alone. In tests to determine whether a candidate synergist increased the effectiveness of a toxicant, it was used at a dosage 5 or 10 times that of the toxicant. Never did it exceed 25 mg. per square foot, because larger amounts caused an oily film with some chemicals. Candidate synergists applied within this rate caused no mortality of female flies exposed for 10 minutes.

Screening tests were first conducted to determine whether selected materials increased the mortality of flies exposed 2 hours after treatment. With some of the promising combinations further tests were conducted to determine the degree of persistence of the residue. Subsequently tests were run to obtain information on the initial and lasting effects of various ratios of toxicant to synergist.

RESULTS OF SCREENING TESTS.—Table 1 gives the results of screening tests to determine the initial effectiveness of candidate synergists in combination with the phosphorus insecticides. Because the candidate synergists cause no mortality within the given rates of application and exposure, the marked increase in mortality caused by combinations over that caused by the toxicant alone would therefore indicate synergistic action. A total of 19 candidate synergists were evaluated. Most of them were tested when combined individually with the 7 selected phos-

Table 2.—Duration of effectiveness of organic phosphorus compounds alone and in combination with several synergists. Compound at 5 mg. and synergist at 25 mg. per square foot for first three combinations and at 1 and 10 mg., respectively, for last two.

Compound and Synergist[1]	Initial Mortality (Per Cent)	Per Cent Mortality After Days as Indicated					
		2	5	12	19	25	33
Malathion							
None	4	0	0	0	0	—	0
1	84	80	58	36	6	—	5
2	4	12	30	4	12	—	7
3	9	—	16	5	0	—	4
4	17	—	11	17	0	—	0
5	26	31	33	43	14	—	35
6	0	4	0	4	0	—	—
7	0	11	7	0	—	—	—
8	0	—	21	0	0	—	0
Compound 21/199							*39 days*
None	22	6	0	0	5	0	0
1	87	64	45	64	—	38	48
2	100	100	73	76	48	0	—
3	100	100	75	58	36	0	—
4	87	87	20	8	0	0	—
5	100	100	100	100	100	89	67
6	64	33	4	0	7	—	—
7	97	100	80	100	95	75	83
8	100	100	100	100	100	100	96
Compound 21/200							
None	4	0	0	0	0	0	4
1	6	0	0	0	0	—	—
2	86	63	40	10	—	0	—
3	64	38	0	0	—	—	—
4	31	13	0	5	0	—	—
5	75	95	81	73	58	30	44
6	10	0	5	0	0	—	—
7	86	82	35	62	64	18	—
8	97	86	88	84	95	79	32
EPN							
None	38	14	0	4	0	0	0
1	98	78	83	53	64	10	0
2	81	46	17	14	0	0	—
3	94	46	17	0	4	—	—
4	100	90	5	0	0	—	—
5	84	73	44	13	14	0	—
6	3	0	0	—	0	—	—
7	96	29	12	5	4	—	—
8	100	68	45	0	0	0	—
Diazinon							
None	23	—	0	0	—	—	—
1	75	—	12	0	—	—	—
2	81	—	71	11	—	—	—
3	59	—	44	3	—	—	—
4	77	—	46	6	—	—	—
5	68	—	71	0	—	—	—
6	13	—	0	0	—	—	—
7	94	—	63	0	—	—	—
8	96	—	94	86	—	—	—

[1] Names of synergists in table 1.

phorus insecticides.

The results show that most of the candidate synergists increased the effectiveness of the toxicants. With some of them the increase was marked. Others had little or no synergistic action on some of the toxicants but marked action on others. Some of the commercial pyrethrum synergists, including piperonyl butoxide (No. 8), sulfoxide (No. 7), and N-isobutylundecylenamide (No. 2), showed improvement with most of the toxicants but piperonyl cyclonene (No. 6) and *n*-propyl isome (No. 9) were less effective.

The data indicate that some of the phosphorus toxicants are activated more than others by the synergists. Compounds 21/199 and 21/200 and Potasan were among the most effective with the synergists tested. Methyl parathion was tested at a lower dosage than these materials and with a 10:1 ratio of synergist to toxicant. The initial toxicity of the toxicant alone was fairly high (51 per cent mortality). The amount of improvement in relation to that of the other materials is therefore not clearly indicated. In general, the synergistic effect with malathion was not so marked as with the other toxicants. However, some of the synergists caused rather noticeable increase in effectiveness.

During the course of this work DDT was compared with the various combinations used. At a rate of 10 mg. per square foot and with the standard 10-minute exposure, DDT failed to kill resistant female flies in any of the numerous tests.

Duration of Effectiveness.—In the tests to determine the duration of insecticidal activity of the toxicant-synergist combinations, the same toxicants were used, with the exception of Potasan and methyl parathion, together with synergists selected from the original 19. Table 2 gives the results of these tests.

In some respects the improvement with the combinations is more readily apparent in these tests than in the tests for initial toxicity. The toxicants alone at the low dosage and the short exposure period of the flies showed little or no initial toxicity, and no toxicity by the fifth day. Some of the synergist-toxicant combinations were highly effective up to 39 days. In general, the data confirm those obtained in the screening tests.

N-isobutylundecylenamide (No. 1) was the best of the synergists tested when combined with malathion and EPN. Piperonyl butoxide (No. 8) was the most effective with compounds 21/199 and 21/200 and Diazinon, although 5-butyl-5-ethyl-2-(3,4-methylenedioxyphenyl) *m*-dioxane (No. 5) and sulfoxide (No. 7) were also highly effective in combination with these toxicants.

Initial Effectiveness and Persistence of Different Ratios of Synergist to Toxicant.—Four toxicants were selected for tests to determine the initial toxicity and duration of effectiveness of different ratios of synergist to toxicant. Some of the synergists that proved most

effective in the previous tests were chosen. The same amount of toxicant was used in each combination. The toxicants were tested alone and with a synergist in ratios ranging from 1:0.5 to 1:10. Since the different toxicants were used in different amounts, the results are not directly comparab e except for EPN and Diazinon.

The results are presented in table 3. The data for some of the combinations are somewhat erratic. They show, however, that the initial effectiveness of each toxicant was increased even with the smallest amount of synergist used and that the initial activity of the combination generally was higher as the amount of synergist was increased.

In general, the duration of effectiveness of each toxicant was also prolonged with increasing amounts of the synergist, although the smaller amounts of synergist in some combinations prolonged the action to a marked degree.

SUMMARY.—Laboratory experiments were undertaken at Corvallis, Oreg., to evaluate the effectiveness of 7 organic phosphorus compounds in combination with 19 candidate synergists against DDT-resistant house flies, *Musca domestica* L. The initial effectiveness, the duration of effectiveness, and the effect of various ratios of the chemical constituents were studied.

The following organic phosphorus compounds were tested: malathion, EPN, methyl parathion, Bayer compound 21/199 (3-chloro-4-methylumbelliferone 0,0-diethyl thiophosphate), Bayer compound 21/200 (3-chloro-4-methyl-umbelliferone 0,0-dimethyl thiophosphate), Potasan (4-methylumbelliferone 0,0-diethyl thiophosphate), and Diazinon (0,0-diethyl 0-(2-isopropyl-4-methyl-6-pyrimidyl) ester of thiophosphoric acid).

It was found that most of the chemicals known to synergize pyrethrum will also improve the effectiveness of certain phosphorus insecticides. The synergists improving the phosphorus compounds included piperonyl butoxide, sulfoxide, chrysanthemumic acid, alpha-propyl piperonyl ester, and 5-butyl-5-ethyl-2-(3,4-methylene dioxyphenyl) *m*-dioxane. Some of the synergists were more effective with certain phosphorus compounds than with others, indicating that chemical structure of the compounds is of importance. The synergists gave a marked increase in initial toxicity and greatly prolonged effectiveness with some of these insecticides. Within the range tested, the

Table 3.—Duration of effectiveness of organic phosphorus compounds when combined with synergists in different ratios

TOXICANT (DOSAGE PER SQUARE FOOT) AND SYNERGIST	RATIO OF TOXICANT TO SYNERGIST	INITIAL MORTALITY (PER CENT)	PER CENT MORTALITY AFTER (DAYS)		
			1	6	12
Malathion 5 mg.					
N-Isobutylundecylenamide	1:0	18	5	4	0
	1:0.5	70	10	15	24
	1:1	67	47	7	9
	1:2	87	52	40	5
	1:5	87	87	69	72
	1:10	97	94	94	80
Hexahydrophthalic acid, di-*n*-butyl ester	1:0	18	5	4	0
	1:0.5	82	0	10	0
	1:1	38	0	10	35
	1:2	88	60	22	47
	1:5	100	50	29	35
	1:10	100	67	100	86
N,N-Diethyl glutaramic acid, ethyl ester	1:0	18	5	4	0
	1:0.5	64	0	0	0
	1:1	87	6	0	10
	1:2	100	14	6	0
	1:5	96	36	12	10
	1:10	100	27	27	88
Compound 21/199, 2.5 mg.					
N-Isobutylundecylenamide	1:0	17	5	0	0
	1:0.5	34	0	0	5
	1:1	39	4	13	0
	1:2	60	5	0	0
	1:5	78	17	8	8
	1:10	84	33	4	60
Piperonyl butoxide	1:0	17	5	0	0
	1:0.5	62	5	36	8
	1:1	90	67	75	48
	1:2	95	95	97	80
	1:5	100	96	100	100
	1:10	100	100	100	100
Sulfoxide	1:0	17	5	0	0
	1:0.5	60	0	12	0
	1:1	77	27	0	0
	1:2	74	28	0	10
	1:5	100	94	70	83
	1:10	100	83	100	96
m-Dioxane, 5-butyl-5-ethyl-2-(3,4-methylenedioxyphenyl)	1:0	17	5	0	0
	1:0.5	71	30	5	0
	1:1	73	27	26	0
	1:2	96	74	35	58
	1:5	98	95	100	88
	1:10	100	100	100	100
EPN 1 mg.					
N-Isobutylundecylenamide	1:0	2	0	0	0
	1:0.5	84	22	80	71
	1:1	82	76	62	14
	1:2	84	92	75	52
	1:5	86	96	96	90
	1:10	96	82	100	100
Piperonyl butoxide	1:0	2	0	0	0
	1:0.5	40	27	11	0
	1:1	85	43	12	5
	1:2	100	100	91	16
	1:5	95	94	53	27
	1:10	94	93	33	35
Diazinon 1 mg.					
N-Isobutylundecylenamide	1:0	0	0	6	—
	1:0.5	5	0	0	—
	1:1	29	—	0	—
	1:2	73	29	14	—
	1:5	48	21	13	—
	1:10	70	55	25	—
Sulfoxide	1:0	0	0	6	—
	1:0.5	20	0	5	—
	1:1	11	0	0	—
	1:2	27	0	0	—
	1:5	81	71	25	—
	1:10	89	80	94	—
Piperonyl butoxide	1:0	0	0	6	—
	1:05	40	7	10	—
	1:1	56	37	15	—
	1:2	70	72	10	—
	1:5	100	91	70	—
	1:10	100	93	93	—

insecticidal activity and duration of effectiveness were increased with increasing amounts of synergist in the phosphorus-synergist combination.

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Tests of Potential Acaricides Against the Lone Star Tick

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As pointed out previously there was such a dearth of information on the lone star tick, *Amblyomma americanum* (L.), that it was decided to set up a series of studies on the ecology, bionomics and control of this anthropod. The initial report summarizes general information on the tick population at Camp Bullis, Texas.

The dense population of the lone star tick at Camp Bullis was responsible for much discomfort and inconvenience to troops in that area. Following the outbreak of "Bullis Fever" (Woodland *et al.* 1943) some work was done on the control of *Amblyomma americanum* at Camp Bullis using BHC, chlordane, toxaphene, DDT and parathion in small plot tests and DDT over large areas (McDuffie *et al.* 1950). None of the chemicals gave satisfactory results. DDT dust at the rate of 40 pounds of 10 per cent dust per acre gave fairly adequate control only after a period of 48 hours from the time of application. The other chemicals tested proved to be less effective than DDT.

Four steps in this study are contemplated: (1) Initial screening tests run by the U. S. Department of Agriculture and other laboratories. (2) Field plot tests as described herein. (3) Area tests on 5 acres each. (4) Regional tests on even larger areas. Troops may be utilized in testing the efficacy of such chemicals under (3) and (4). After consultation with representatives of the U. S. Department of Agriculture it was decided to initiate a series of field plot tests on various concentrations of dusts in an attempt to find a chemical that would provide: (1) an initial rapid knockdown, and (2) a reasonably long residual effect.

MATERIALS AND METHODS.—It was decided to test the chemicals in several concentrations using pyrophyllite as a diluent and applying them in the form of dusts to 0.025-acre plots. A number of such plots with high tick populations were selected and one or more 9 square foot quadrats were selected and marked. These were used for the counts each time, both before and after treatment. Similar undusted plots were utilized as controls and the degree of control calculated by Abbott's formula.[2]

Quadrat counts were made by spreading a piece of white flannel cloth (1 yard square) on the ground for 10 minutes with the observer standing or kneeling

[1] Grateful acknowledgment is made to the following for their enthusiastic participation in these experiments: D. E. Potts, M. G. Radke, J. S. Williams, and J. E. Webb, Jr.

[2] $\frac{x-y(100)}{x}$ = per cent net control

x = per cent alive in control
y = per cent alive in treatment

on the cloth. This was supplemented by putting an 18- by 30-inch towel at each of the four edges of the square for 2 minutes. Adults were collected, nymphs and larvae counted, and all were removed from the cloth and towel and returned to the quadrat. Counts were made on the day prior to the dusting of the plots; 24 hours after dusting, 48 hours after dusting and at weekly intervals thereafter.

Standard rotary type dusters were utilized, the applications being made at the rate of 40 pounds of dust per acre. The dusters were filled and weighed before and after application until the correct amount of dust had been applied to each plot. Applications were made in the early morning hours to overcome interference from the wind. The actual amount of toxicant applied to each plot was varied by altering the per cent of diluent in the dust applied at the rate of 40 pounds per acre.

The tests were run in three phases with one concentration of each insecticide applied in each phase. Three plots were dusted with each concentration of the insecticide. Five undusted plots were used as controls in each of the three phases. The dusting of the plots used in the first phase took place in June and that of the second and third phases in July.

The following chemicals were tested at the concentrations indicated:

Phase I—
- Dieldrin —0.25 lb/acre } Test Chemicals
- Aldrin —0.25 lb/acre } Test Chemicals
- Lindane —0.05 lb/acre } Test Chemicals
- DDT —1.0 lb/acre } Controls
- Chlordane—1.0 lb/acre } Controls

Phase II—
- Dieldrin —1.0 lb/acre } Test Chemicals
- Aldrin —1.0 lb/acre } Test Chemicals
- Lindane —0.25 lb/acre } Test Chemicals
- DDT —4.0 lb/acre } Controls
- Chlordane—4.0 lb/acre } Controls

Phase III—
- Dieldrin —0.5 lb/acre } Test Chemicals
- Aldrin —0.5 lb/acre } Test Chemicals
- Lindane —0.1 lb/acre } Test Chemicals
- DDT —3.0 lb/acre } Controls
- Chlordane—3.0 lb/acre } Controls

RESULTS.—Results of the effectiveness of the various materials used in the tests are summarized in table 1. Dieldrin at the rate of 1 pound per acre gave a greater initial reduction of ticks within 24 hours than any of the other chemicals tested including both chlordane and DDT at 4 pounds per acre (Table 1). Eight weeks after application dieldrin at 1 pound per acre demonstrated a continued high rate of reduction which was exceeded only slightly by that of DDT at 4 pounds per acre. At the rate of 0.25 pounds per acre dieldrin gave satisfactory control over a period of 8 weeks, but did not reach an acceptable rate of reduction until 48 hours after application.

Results obtained from tests of aldrin

Table 1.—Summary of the control obtained with various dusts against the lone star tick in 1952.

DUSTS—POUNDS PER ACRE	TICKS BEFORE DUSTING	PER CENT REDUCTION AFTER						
		24 Hrs.	48 Hrs.	1 Week	2 Weeks	4 Weeks	6 Weeks	8 Weeks
Dieldrin								
0.25	491	78.5	91.9	94.7	97.5	98.5	97.8	94.8
0.5	415	91.7	96.3	97.1	97.7	94.2	83.5	
1.0	1087	97.9	98.7	99.4	99.6	98.5	95.8	92.7
Aldrin								
0.25	337	82.2	89.5	91.0	95.1	94.1	94.5	83.1
0.5	337	87.8	92.0	77.3	94.9	82.9	0.0	
1.0	273	73.7	80.2	88.6	78.1	90.8	75.4	74.8
Lindane								
0.05	547	84.9	86.3	65.6	61.3	73.2	76.9	54.7
0.1	360	89.6	90.9	81.4	72.0	66.1	9.5	
0.25	421	94.9	95.1	86.5	87.7	83.5	64.1	76.9
DDT								
1.0	190	25.3	48.4	67.7	80.8	80.6	90.4	72.0
3.0	267	71.9	75.5	61.5	72.7	20.1	0.0	
4.0	287	83.7	90.3	95.6	96.5	97.5	93.0	95.9
Chlordane								
1.0	277	72.0	85.1	91.8	92.3	94.5	93.6	92.5
3.0	250	91.5	97.7	94.3	94.4	92.6	45.2	
4.0	290	94.5	95.6	91.2	95.0	87.4	86.3	62.3

and lindane were erratic and indicated that these materials were not suitable for control of *Amblyomma americanum.*

DDT at 4 pounds per acre gave adequate control of *Amblyomma americanum* over an 8 week period but was not effective until 48 hours after application. These results substantiate those obtained by McDuffie *et al.* in 1950. At the rate of 1 pound per acre DDT gave an unsatisfactory degree of control.

Chlordane at 4 pounds per acre was effective in reducing the tick population within 24 hours, but did not maintain this high rate of control over an 8 week period.

Tests of dieldrin and aldrin at 0.5 pounds per acre, DDT and chlordane at 3 pounds per acre, and lindane at 0.1 pounds per acre were made so late in the season that tick populations fell off sharply in the control plots. This had an adverse effect upon the latter portion of the series.

DISCUSSION.—From the standpoint of both initial kill and residual effect dieldrin applied at the rate of 1 pound per acre appears to be superior to DDT and chlordane at rates up to 4 pounds per acre, aldrin at 1 pound per acre, and lindane at rates up to 0.25 pounds per acre. Results of these plot tests indicate that ticks in bivouac areas may be reduced to a low population in 24 hours or less by applying dieldrin as a dust at the rate of 1 pound of toxicant per acre. Since the question of the activity of *Amblyomma americanum* in relation to moisture has been raised (Smith & King 1950) it should be noted that the total measurable precipitation during the test period was slightly less than 4 inches. This report gives the results of the second step in testing new acaricides. It is planned to test others. Following this, the most promising of these chemicals will be further tested in areas of 5 acres each.

SUMMARY.—In the summer of 1952 plot tests of various materials against the lone star tick were carried out at Camp Bullis, Texas. Results indicate that dieldrin applied as a dust at 1 pound per acre is more effective in controlling the lone star tick, *Amblyomma americanum* (L.), than any of the other chemicals tested.

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RECENT ADDITIONS TO DEPARTMENT OF ENTOMOLOGY, UNIVERSITY OF WISCONSIN

On July 1, 1953, Donald A. Dever, B.S.—Ontario Agr. Coll., 1949 (Ph.D.—Wis., 1953) received an appointment as assistant professor to handle fruit insect problems for the Agricultural Experiment Station. Fred Marzke (Ph.D. Zoo., Michigan State, 1953) was transferred December 1, 1953, by the U.S.D.A. to the Wisconsin Station to cooperate with Dr. R. J. Dicke on cheese mite control. Daniel M. Benjamin (Ph.D.—Minn., 1950) appointed February 1, 1954 as assistant professor to work with Dr. Roy D. Shenefelt on forest insect problems. E. Paul Lichtenstein (Ph.D.—Hebrew Univ., Jerusalem, 1948) became a project associate on February 1, 1954 to direct North Central Regional Project-19 "Accumulation of Pesticide Chemicals in the Soil." John E. Casida (Ph.D.—Wis., 1954) appointed assistant professor April 1, 1954 to teach toxicology and conduct research on the metabolic aspects of insecticides.

Effectiveness of Cattle-Rubbing Devices and Hand Dusting for Horn Fly Control

ARTHUR W. LINDQUIST and ROBERT A. HOFFMAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Simplifying and reducing costs of application of insecticides to animals or crops is an important part of entomological research. Spraying cattle with DDT and other insecticides has given good control of the horn fly, *Siphona irritans* (L.), for several years and is a recommended procedure. Observations have shown, however, that many stockmen are not following a consistent program of spraying because of the work involved, and frequently refrain from spraying because of possible weight loss in roundup and handling of stock. This is an unfortunate circumstance, since it has been demonstrated that control of large populations of horn flies will increase weight gains of beef cattle by 42 to 70 pounds in 2 to 3 months (Laake 1946). Horn flies have been estimated to reduce milk yield from 10 to 20 per cent.

RUBBING DEVICES.—Rogoff (1952) and Rogoff & Moxon (1952) reported on studies in which cattle treated themselves with insecticides by rubbing against "cable-type" devices. A chain or several strands of barbed wire were suspended between two posts. Burlap sacks were wrapped around the chain or wire and soaked with insecticide-oil solution. They reported excellent control of horn flies, and showed further that DDT residues in the fat of cattle using these rubbing units for an entire season average 1.8 p.p.m., whereas cattle sprayed three times with 0.5-per cent DDT showed an average of 14.9 p.p.m. in the fat.

The self-treatment units are of interest in that advantage is taken of the habits of both cattle and horn flies. It is common knowledge that cattle rub or scratch themselves on posts, trees, fences, or any object that offers some resistance. Horn flies spend most of their life cycle on the animal, and are thereby in continuous contact with any insecticide present on the cattle.

In order to evaluate the usefulness of rubbing units under Oregon conditions, several experiments were conducted in 1952. Tests were made in the Willamette Valley in western Oregon (Benton County) and in Lake and Klamath Counties in eastern Oregon. These areas differ in climate, altitude, and general topography. The rubbing units were similar to those used by Rogoff; i.e., the length of cable was 10 to 20 feet, and burlap sacks were wrapped singly around the cable and fastened with heavy twine (Fig. 1).

FIG. 1.—Rubbing device set up in irrigated pasture, Klamath Co., Oregon.

Special care was given to place the devices near salt licks, water troughs, or places where the cattle would loaf or frequent, because the success of the control is dependent on the cattle rubbing against them. In pastures of 1000 acres or more, with 100 to 200 head of cattle, several rubbing units may be necessary. The insecticides used were DDT, chlordane, and pyrethrum plus piperonyl butoxide, at different concentrations, applied at 1 to 2 gallons, or just enough to wet the sacks. Reapplication was not made until it was evident that the horn fly population was building up. The formulations are indicated in table 1.

Most of the insecticides were 25-per cent emulsifiable concentrates diluted to 5 per cent with fuel oil. One treatment of

Table 1.—Control of horn flies with cattle-rubbing devices treated with various insecticides, Oregon, 1952. One rubbing unit used per test.

Ranch	Number of Cattle	Pasture Approximate Acres: Cleared	Pasture Approximate Acres: Brush and Trees	Insecticide[1]	Flies per Animal: Before Treatment	Days After Treatment: 3–5	8–13	15–20	21–25	26–30	31–41	42–50	51–70
Benton County													
1	21	48	2	DDT 5%[2]	168	4	0	0	0	0.6	0.6	2	0
2	35	40	—	DDT 5%[2]	168	0	0	0	.2	0	0	156	—
3	25	15	—	DDT 5%	166	0	0	0	1	0	.2	2	6
4	12	12	4	DDT 5%[3]	160	2	0	0	2	—	2	—	—
5	15	25	—	Pyrethrum[4]	32	4	4	32	—	32	.2	—	—
6	18	25	—	Pyrethrum	300	196	186	62	—	—	—	—	—
7	15	10	3	DDT 5%	86	4	0	8	—	4	2	0	10
8	200	150	1150	DDT 5%	3332	2332	1366	2266	—	—	—	—	—
9	—	—	—	No treatment (check)	—	618	820	920	1040	700	850	900	—
10	25	40	—	Chlordane 2.5%	400	206	220[5]	20	—	28	26	30	26
11	10	18	—	DDT 2.5%	290	18	26[6]	1.2	—	20	20	16	4
12	8	20	20	Chlordane 5%	180	8	10	2	—	—	0	—	—
13	4	10	—	Chlordane 5%	158	.2	0	—	—	—	0	—	—
14	46	25	50	Chlordane 6.5%	480	18	12	.6	—	1	—	—	—
14–16	—	—	—	No treatment (check)	—	—	882	—	—	1832	1666	—	—
Lake County													
17	5	15	5	DDT 5%	380	—	2	0	0	—	—	—	—
18	10	20	0.2	Pyrethrum[4]	360	—	114	90	—	—	—	—	—
19	8	15	—	Pyrethrum	240	—	8	12	126	—	—	—	—
20	120	80	—	DDT 5%	2840	—	0	0	—	—	—	—	—
21	40	40	—	DDT 5%	1720	—	0	0	10	—	—	—	—
22–23	—	—	—	No treatment (check)	—	—	1450	1400	1100	—	—	—	—
Klamath County													
24	80	80	Some	DDT 5%	150	—	92	0	—	—	—	—	—
25	120	100	—	DDT 5%	400	10	0	—	0	—	—	—	—
26	65	40	—	Chlordane 5%	100	20	20	—	—	—	—	—	—

[1] Emusifiable concentrated diluted with fuel oil unless otherwise stated.
[2] Technical DDT dissolved in fuel oil.
[3] Technical DDT dissolved in fuel oil plus 20% of motor oil SAE 30.
[4] Pyrenone (0.2% of pyrethrins, 2% of piperonyl butoxide in fuel oil).
[5] 3 quartz of 5% chlordane added.
[6] 3 quarts of 5% DDT added.

the sacks with this preparation gave good horn fly control for 30 to 70 days.

Failure of the rubbing device to control horn flies occurred on ranch 8. This large pasture was overgrown with trees and had a creek meandering through it. The one unit was not being used by the cattle. In such a situation several units strategically placed might have given control.

Pyrethrum plus piperonyl butoxide gave poor to fair control. Chlordane and DDT at 2.5-per cent concentration were compared in two similar situations (ranches 10 and 11). As chlordane did not control the flies, retreatment was made with both materials at 5 per cent, which gave good control for 55 days. Three other tests with chlordane in Benton County gave good results.

Checking on the tests in Lake and Klamath Counties was not continued for long periods, but it was evident that good horn fly control was obtained. Since most of these tests were conducted in open, irrigated pastures, there were not many objects to compete with the rubbing units. In nearly every place, however, there were numerous posts, corrals, sheds, or trees on which the animals could rub, but it was evident that they were using the insecticide-treated devices. Numerous observations were made on the effect of these insecticides and rubbing units on horse flies, deer flies, mosquitoes, and stable flies, but in no case was it indicated that control was obtained.

HAND DUSTING.—Surveys and observations had indicated that many owners of 1 to 20 head of dairy cattle did not want to bother with horn fly control because of the trouble of preparing sprays for use in small sprayers. In 1950 and 1951 the hand application of 50-per cent methoxychlor wettable powder on the backs and sides of cattle was tried in Oregon as a means of reducing labor and cost of treatment. A small handful or heaping tablespoonful of the powder was sprinkled on the animal and rubbed in lightly. This amount contains roughly the same amount of methoxychlor as 1 to 2 quarts of a 0.5-per cent spray. It was found that a cow could be dusted in 30 seconds or less.

Close observation on two head of cattle for two seasons showed effective horn fly control for 3 weeks with one application. Dairy herds of 10 to 15 cows having

high horn fly populations were treated with the hand method. Good control was obtained for 3 weeks. Several small dairy operators took up the hand application of methoxychlor wettable powder, and they all reported good results and were pleased with the ease and speed of treatment. It is doubtful whether owners of 50 or more cattle would be interested in this method, but for the small operator it does seem to have merit.

SUMMARY.—Control of horn flies *Siphona irritans* (L.), on livestock has been obtained in Oregon for 30 to 70 days following a single application of DDT or chlordane in oil to Rogoff-type rubbing devices. Small dairy herds have received up to 3 weeks' protection after a hand-dusting application of a tablespoonful of 50-per cent methoxychlor wettable powder to the backs and sides of the animals.

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Response of the Pink Bollworm Moth to Certain Ultraviolet and Visible Radiation

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It is well known that artificial lights attract some insects but not others. Since the development of new sources of light radiation, increased interest has been shown in determining their effect in attracting different species.

REVIEW OF PREVIOUS INVESTIGATIONS.—Gui *et al.* (1942) made important observations and experiments with the response of insects to color, intensity, and distribution of light. They found that lamps of all colors attracted insects to some degree. They used gold and blue fluorescent, incandescent white, and bare yellow lamps, and lamps of different wattage. Blue light was most attractive, followed in order by white, yellow, and red.

Taylor & Deay (1950) conducted research on the use of radiant energy to control the European corn borer, *Pyrausta nubilalis* (Hbn.). Fluorescent lamps were used, with grids for killing the moths as they were attracted to the lamps. Studies were also made with sources radiating the complete ultraviolet and visible mercury-vapor spectrum at relative intensities of 1 and 3, and the respective catches were 40 and 60 per cent of the total. They later made improvements in the light traps, both in the grids and in the type of insulators and transformers (Taylor *et al.* 1951).

Girardeau *et al.* (1952) experimented with three types of traps at Tifton, Georgia. One trap consisted of a backboard painted fluorescent green and lighted by two 30-watt, black-light fluorescent tubes. Another was a suction-type trap, consisting of a vertical 4-vaned baffle painted fluorescent green, with a 15-watt fluorescent black-light in each quadrant. Vertically beneath the baffle and bulbs was located a 1/6-hp. motor operating a 4-bladed fan with the air blast directed downward. The third was an electrocutor-type trap, with four 300-watt, clear-glass incandescent bulbs placed under a metal hood, the inside of which was painted white. A grid was powered from a transformer under the hood and carried 9000 volts at 18 milliamperes. The suction trap appeared to be the most effective.

Frost (1952) studied light traps of all types, including the types used from about 1886 up to 1950. He concluded that the earliest traps were unsuccessful because suitable lamps were not available. As lamps became more satisfactory,

[1] In cooperation with the Texas Agricultural Experiment Station.

traps gained popularity and were used extensively for obtaining information on the abundance and distribution of insects. He further concluded that light traps had not been used extensively or successfully as a means of control.

In 1951 the authors operated two of the special black-light traps, similar to those found to attract the European corn borer, at College Station, Texas, in a study of their attractiveness to the bollworm, *Heliothis armigera* (Hbn.). They found that this insect was highly attracted to this source of light radiation.

Early studies on the attractiveness of lamps to the pink bollworm, *Pectinophora gossypiella* (Saund.), were in conflict with regard to the phototropic response of this insect. McClelland & Sahr (1911), Sturm & Zimmerman (1912), Zacher (1913), Ballou (1920), Willcocks (1916), and Gough (1918) all concluded that it probably was attracted to lights.

However, Busck (1917) concluded that "from very many and repeated observations under different conditions it may be definitely stated, notwithstanding the many other statements to the contrary, that *Pectinophora gossypiella* is not attracted to light, but is, on the contrary, shy of all light, natural and artificial." Loftin *et al.* (1921), from work conducted in Mexico, concluded that "the few pink bollworm moths that did come to the lights were probably ones that we disturbed in moving about, and it cannot be said there was any attraction whatsoever to the light." A. J. Chapman and L. W. Noble, in limited experiments conducted at Presidio, Texas, in 1928 (unpublished data) found that some pink bollworm moths were attracted to artificial lights, especially to a blue incandescent source.

After the rapid spread of the pink bollworm to previously uninfested areas of the Cotton Belt in 1950 and 1951, it was thought advisable to determine the response of this insect to some of the new sources of light radiation that had recently shown promise in attracting certain other insects.

TRAPS AND RADIATION SOURCES.—Two types of traps were used, the mercury-vapor trap and the black-light trap. The mercury-vapor trap consisted of a galvanized-iron funnel approximately 30 inches long with a 12-inch opening at the front and a 3-inch opening at the rear. A

FIG. 1.—Insect trap equipped with a mercury-vapor lamp and a 0.25-inch screen grill to exclude larger insects. A cyanide jar is screwed to the bottom of funnel. Switch and time clock for controlling the electric current are shown.

100-watt mercury-vapor lamp was mounted horizontally at the small end of the main funnel. A vertical rectangular funnel, opening into the larger horizontal funnel and mounted beneath and perpendicular to the main funnel, tapered into a mason jar charged with calcium cyanide, in which the moths attracted to the lamp were collected (Fig. 1).

The mercury-vapor lamp is of the spot type and casts a narrow, concentrated beam of bluish-white light in the visible region of the spectrum. The lamp radiates throughout the principal mercury lines from 2967 to 5780 Angstrom units, with 0.05 watt radiated in the middle ultraviolet region (2800 to 3200 A.), 2.2 watts in the black-light or near ultraviolet region (3200 to 3800 A.), and 7.75 watts in the visible region (3800 to 7600 A.).[2]

These traps were mounted 6 to 8 feet above the ground, usually on the side of conveniently located utility poles. At this height the cone-shaped beam of radiation

[2] Lamp Bulletin LD-1, General Electric Company, October 1950, p. 40.

(42.5° in the horizontal plane) gave perceptible illumination over approximately 2 acres. A 0.25-inch mesh hardware cloth was used over the main funnel opening to screen out the larger insects attracted to the trap (Fig. 1).

The black-light trap was a commercial suction-type light trap, which had been modified by the addition of a rain hood and a collection funnel (Fig. 2). The suction-fan motor was made inoperative to prevent damage to the specimens. The

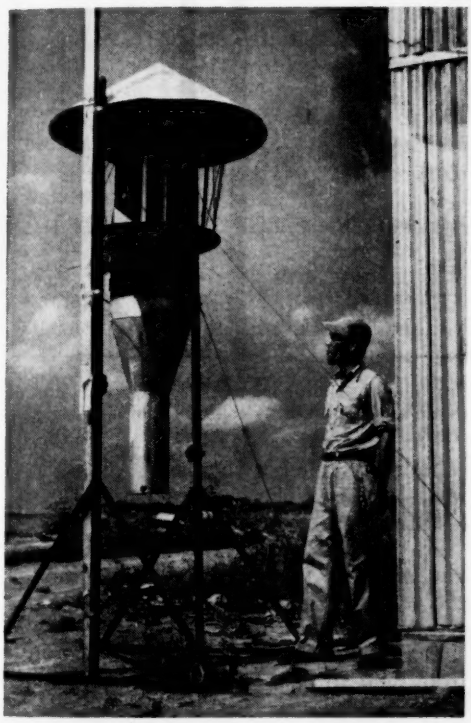

FIG. 2.—Black-light trap equipped with superstructure for rain protection and a funnel that contains a 1-gallon cyanide jar at the bottom. A hinged trapdoor at the bottom of the funnel permits handling the cyanide jar. Two black-light fluorescent tubes may be seen in vertical position between baffles.

trap was equipped with four 15-watt black-light fluorescent lamps. The four lamps, approximately 18 inches long, were mounted vertically at the top of the trap in a 4-vaned baffle assembly. The baffle was painted with a fluorescent green paint and each quadrant contained one of the 15-watt lamps, so that the radiation covered a full 360° in the horizontal plane. The baffle assembly was mounted on the fan housing, which consisted of a metal cylinder 16.5 inches in diameter and 14 inches in height, with a flared top approximately 28 inches in diameter. The collection funnel with a cyanide jar was attached to the bottom of the fan housing.

The black-light fluorescent lamp is a low-pressure mercury-vapor lamp, with special ultraviolet transmitting glass coated with a blend of fluorescent phosphors to produce radiant energy peaked at 3650A. The 15-watt lamp produces 2.1 watts of radiant energy in the black-light or near ultraviolet region and 0.4 watt in the visible region, with no radiation in the middle and far ultraviolet regions of the spectrum.[2]

All traps were controlled by time clocks adjusted to turn them on at dusk and off at dawn.

LOCATION OF TRAPS.—The San Benito area of the Lower Rio Grande Valley in Texas was selected for the first tests, because of the intensity of infestation there at the close of the 1951 season and because a subsequent mild winter in that area indicated a heavy carryover and emergence during 1952. Six mercury-vapor and two black-light traps were operated from March 27 to December 31. After it had been determined that these light sources were definitely attractive to the pink bollworm moth, traps were placed in the Corpus Christi, central, and north Texas areas, and in Louisiana and Mississippi.

TESTS IN SAN BENITO AREA.—From April until June, few pink bollworm moths were collected. Weather conditions were mostly unfavorable for emergence, as an excessively dry winter delayed the emergence of the moths. During May nearly 6 inches of rain was recorded in the San Benito area, with about 2.5 inches in June. This amount of moisture, together with a rise in temperature, accelerated emergence of moths during July and August. The numbers of pink bollworm moths collected throughout the season in the area are shown in table 1 and figure 3.

As may be noted in table 1, the peak of attraction was reached in July.

Some difference was found in the numbers of insects, particularly the pink bollworm moths, that were attracted to the two types of traps. A comparative test was therefore conducted, in which a mercury-vapor light trap, having a 42.5° radiation in the horizontal plane, was placed within a few feet of a black-light

Table 1.—Collections of pink bollworm moths in light traps located in the San Benito area of Texas, from March 27 through December 1952. (8 traps operated unless indicated otherwise.)

Month	Number of Trap-Nights Operated[1]	Number of Moths Collected	
		Total	Average per Trap per Night
March	30[2]	12	0.40
April	210[3]	233	1.11
May	199	105	.53
June	227	552	2.43
July	194	190,708	983.03
August	207	100,348	484.77
September	109	3,476	31.89
October	230	103	.45
November	240	3	.013
December	248	2	.008

[1] Number of nights the traps were in operation times the number of traps operated.
[2] 6 traps.
[3] 7 traps.

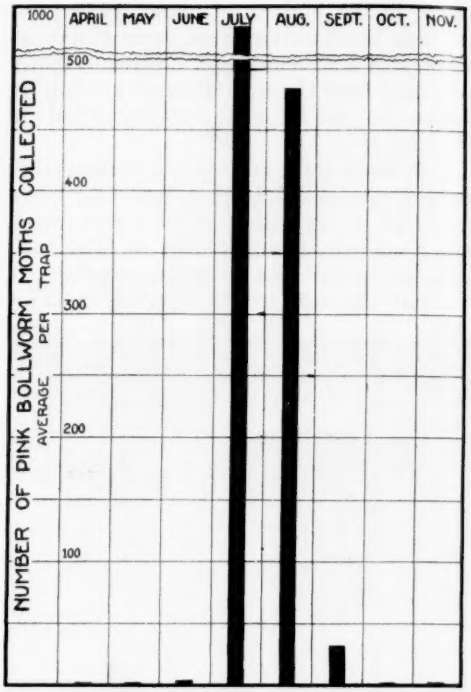

FIG. 3.—Seasonal populations of the pink bollworm moth as determined by collections in insect traps.

trap, having a 360° radiation, in a heavily infested area. In two periods—from August 14 to 26 and from September 3 to 11—approximately 34 times as many pink bollworm moths were collected in the black-light as in the mercury-vapor trap.

On August 28 about 16,760 moths were collected in a black-light trap, with an estimate of more than 96,000 in the actual trap (funnel) that could not enter the cyanide jar. This was the maximum number of moths taken in this type of trap on any one night. This trap was in a most favorable location, however, as a field of late cotton practically surrounded it. The cotton remained green and succulent until the stalks were destroyed on August 28. While frequently dusted for boll weevil and leaf-worm control, it was still a focus for the pink bollworm moth. Moreover, much of the cotton in the surrounding area had already been destroyed, as the final stalk-destruction date was August 31. It was apparent that moths flew into this field in great numbers. The number taken in the trap (cyanide jar) dropped to 1,715 on August 29, and to 34 on September 6.

The maximum number of pink bollworm moths taken in the mercury-vapor trap in any one night for the season was 23,666 on July 27. It was estimated that an additional 20,000 to 30,000 were actually in the funnel of this trap but could not enter the cyanide jar, because it was completely filled with insects. This trap was also located in an area where the infestation was heavy.

As the cotton became less succulent and suitable for egg deposition, and as the stalks in many of the fields were destroyed as soon as picking was completed, the moths began their migration, flying from field to field in search of more suitable host plants. Although at least 16 known wild and cultivated host plants other than cotton occur in the Valley, they are not so abundant as cotton. When the cotton stalks were completely destroyed by August 31, and the available food plants reduced to a minimum, the moths accordingly began their "suicidal flight," and died within a few days. The collections in the traps were immediately reduced.

The weather definitely affected the number of pink bollworm moths collected at any one time. Temperature was doubtless the controlling factor, as below 60° F. few moths were taken. Rain following a long, dry period stimulated the pupae and softened the hard, dry soil, permitting

the moths to emerge. Wind velocity was also an important factor. When temperatures and other meteorological factors were favorable, and the wind velocity was over 10 miles per hour, the number of moths taken was greatly reduced. On nights when the air was calm or the wind did not exceed 6 miles per hour, with other factors being equal, a greater number of moths were collected.

It was important to determine the sex ratio of moths collected in the light traps. About 11,535 moths were selected at random and examined during July and August. In July 70 per cent of them were males and in August 75.5 per cent. However, in the field the sex ratio was closer. Observations by A. J. Chapman at Brownsville indicated that males predominated slightly.

Willcocks (1916) collected about 5,856 pink bollworm moths in a light trap in Egypt, of which 58 per cent were males. He found that 65 per cent of the females contained large numbers of eggs, but included in this figure were females that had laid part of their eggs previous to capture.

Of the female moths collected in 1952, the greater number were gravid. Often almost perfect female moths were collected, indicating that moths had just emerged or if they had been fertilized (mated) the eggs had not developed. A number of female pink bollworm moths were also dissected and egg masses were found. Although some of the moths in the traps were probably spent, a large proportion doubtless were gravid.

TESTS IN CORPUS CHRISTI AREA.—The Corpus Christi area included the areas around Port Lavaca, Taft, Robstown, and Kenedy, which were so grouped to be separate from the San Benito area. In the Corpus Christi area, especially around Taft, infestation of pink bollworms was very heavy. In August a mercury-vapor trap was placed near cotton fields in each of these places and collections were made through November. The results of these collections are given in table 2.

TESTS IN PARIS AREA.—In September 1952 mercury-vapor traps were placed in the northeastern part of Texas, with two each in the counties of Red River, Lamar, and Fannin. At that time these counties were not known to be infested with the pink bollworm, and no moths were collected that month. However, one moth was taken in Lamar County on October 6, one in Fannin County on October 11, and one in Red River County on October 15.

Table 2.—Number of pink bollworm moths collected in mercury-vapor traps in the Corpus Christi area of Texas. 1952.

LOCALITY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
Port Lavaca	1530	1078	32	11
Taft	5986	3998	334	66
Robstown	3334	1673	3	0
Kenedy	577	482	10	—

Late in October the light-trap collections in Lamar, Red River, and Fannin Counties were discontinued, and the traps were moved to the nearby counties of Hopkins and Bowie, which were not known to be infested. No pink bollworm moths were taken in these counties. This may possibly have been due to weather, as frost and freezing temperatures were recorded in this area shortly before the traps were relocated.

TESTS IN OTHER AREAS.—One mercury-vapor trap was placed in each of Brazos, Burleson, and McLennan Counties. Four pink bollworm moths were taken in Burleson County and two in Brazos County; none was taken in McLennan County. However, these counties were previously known to be infested. Mercury-vapor traps were also placed in Louisiana, one each in the Shreveport, Natchitoches, and Tallulah areas. One trap was also placed at Stoneville, Miss. No pink bollworm moths were collected in any of these traps.

One mercury-vapor trap and one blacklight trap were placed in a cottonseed warehouse at Lamesa, Texas, to determine whether any pink bollworm moths would be collected from untreated seed in storage. On October 27 a single moth was taken in the mercury-vapor trap. However, the traps were not placed in the warehouse until late in October, when temperatures were gradually getting lower.

Ballou (1920) used lamps for collecting pink bollworm moths in a large warehouse in Egypt, where cotton seed was stored, and collected several thousand moths in 8 days.

SUMMARY AND CONCLUSIONS.—Mercury-vapor and black-light fluorescent lamps were used in specially designed insect traps for attracting the pink bollworm moth, *Pectinophora gossypiella* (Saund.).

Six mercury-vapor and two black-light traps were placed in Texas, in the San Benito area of the Lower Rio Grande Valley, and were in operation from March 27 to the end of 1952. In August mercury-vapor traps were located near Port Lavaca, Taft, Robstown, and Kenedy, and later in the counties of McLennan, Burleson, Brazos, Fannin, Lamar, Red River, Bowie, and Hopkins. Traps were also in operation in Louisiana and Mississippi during the latter part of the season.

In a single night in the San Benito area approximately 50,000 pink bollworm moths were collected in a mercury-vapor trap and about 112,000 in a black-light trap. In general the black-light traps were more effective than the mercury-vapor lamps in attracting the pink bollworm moth.

One pink bollworm moth was taken in mercury-vapor traps in both Lamar and Fannin Counties, which counties were previously free from infestation.

One moth was collected in a mercury-vapor trap placed in a cottonseed warehouse in Lamesa, Texas, in October 1952.

Some of the uses to which the traps might serve to advantage and on which further research is in progress include (1) a direct means of control, (2) in pink bollworm migration studies, (3) in detecting the presence of the pink bollworm and cotton leafworm in a given locality, (4) as a criterion for timing insecticide applications, (5) in comparing the density of the pink bollworm infestation from year to year, and (6) for determining the length of the light waves that attract the greatest number of moths.

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The Control of Insect Flight in Food Processing Plants by Residual Insecticides

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Among the health, legal, and esthetic requirements of clean and wholesome food production is the maintenance of the control of various insects, among them the house fly. In many food processing plants an important aspect of control is the control of flight, that is the prevention of entry or flight after entry. Screens and insecticides may be used to restrict the passage of flies into the establishment. The practice of sanitation to present an unfavorable environment to all stages of the insect is a basic control method. Insecticides may be used to control the movements of insects once they are in the building.

The screening of all points of entry is not feasible in some food establishments. Many canneries are so constructed that it is not desirable for much-used doorways, for example, to remain closed during the peak of the canning season. Most plants have a few points which can not be protected by this method.

Sanitation in regard to fly propagation can be maintained to a very satisfactory degree around food plants provided a conscientious and continual effort is made to correct contributing factors on the immediate premises. This particular effort may not control the flight of flies to the necessary degree because of conditions in the surrounding area.

The use of insecticides has been invoked as a means of aiding the two means mentioned above or as a measure complete in itself. The effectiveness of this method of control under certain conditions can be augmented by the application of the residual or persistent types of insecticides.

No data are at hand regarding the flight activities of exposed or non-exposed flies in food establishments, especially as regards distance of flight from points of entry or contact after exposure to insecticides. There is considerable information, on the other hand, concerning the distance a house fly can travel from a point of dispersal in a town or the country (Bishopp & Laake 1919, 1921; Derbeneva-Ukhova 1922; Hindle 1914; Hindle & Merriman 1914; Lindquist *et al.* 1951; Parker 1915, 1916a, 1916b; Schoof *et al.* 1952; Yates *et al.* 1952).

The effectivensss of residual insecticides in controlling the flight distance of insects in food plants has been questioned. A marked variability in initial activity and duration of effectiveness of residual deposits of certain insecticides has been reported. The need to obtain consistently good performance from such residues is imperative if they are to be used in this type of establishment.

This paper presents results, from both preliminary laboratory tests and actual work in food processing buildings, carried out in order to develop a better understanding of insect flight after exposure to residual action insecticides under food processing conditions.

Materials and Methods.—The house fly *Musca domestica* L., was selected for experimental use as a typical winged insect to be found around food establishments. A strain non-resistant to the persistent type of insecticides was reared in the laboratory on a cereal medium to which powdered skim milk was added on the second day. The culture medium was kept in 8- by 8-inch animal jars. The larvae were allowed to pupate in the medium. The pupae were separated from the medium and selected for either experimental or breeding purposes. Both sets of emerged flies were provided with water and fed on diluted condensed milk.

Wooden ply board panels 1 foot square were treated with various residual insecticides; these were used as resting surfaces for flies released in buildings. Panels half the above size were used in laboratory tests. Sprays were applied by a hand sprayer until the surfaces were wet to the point of run-off. Residues used were aged 1 hour, 1 day, 1 week, 1 to 6 months inclusive, and 9 and 12 months. Flies for experimental use were on the average 4 days old, and were chilled to the point of sluggishness for ease of handling preliminary to exposure. Flies were allowed to become active just prior to exposure at room temperature.

Insecticides used in tests were aldrin, allethrin, benzene hexachloride, chlordane, DDT, dieldrin, ditolyl trichloroethane, methoxychlor, piperonyl butoxide-pyrethrum mixture, TDE (DDD), and toxaphene. Pyrethrum was used as a check insecticide; there was no great variation between laboratory and field data.

Concentrations (as weight/weight percentages) used were those generally recommended by manufacturers for house fly control. In addition, a higher and lower concentration were also used to check the effect of recommended dosages on flight. For uniformity of application, toxicants, with two exceptions were applied in a refined kerosene base. DDT was also applied in lacquer and paint bases. In the latter instance application was as thick (wood completely covered) and thin (wood barely showing) coats.

Checks were made with each exposure; no knock-down was observed. The mortality among check flies ranged from 0 to 12 per cent during a 24 hour period.

In the laboratory, four replications each of 25 flies were used; each replication contained flies from at least two cultures. Two sets of exposure times were used in the laboratory. The first, used because in many instances plant activity is such that flies may rest for a very short time on sprayed surfaces, was comprised of 0.5, 1, and 2 minutes. The second included 10 20, and 30 minute exposures; these were used because they seemed to form the range of ordinary resting time in situations of moderate temperatures. The continuous exposure of flies to an insecticide for 1 or more hours is not regarded as a common situation in the field. Exposed flies were released to cages of 2 square feet or to a room 18 feet square, provided with food and water, and held at room temperature. Untreated check flies were held in the same manner.

The flies held for laboratory observation were observed for at least 3 hours each day to obtain flight data. From actual observation of many marked, unexposed flies it was determined from data concerned with time elapsed for distance travelled that about 10 per cent of the life of such flies might be spent in flight. This figure was used as a guide to estimate flight distance of exposed flies in the laboratory; the actual time in flight was of course determined by the age and strength of the insecticide involved as well as the room temperatures.

Two dissimilar types of food establishments, both situated in the East Bay area, were used in the tests. One was a cannery of concrete construction. It measured 550 by 300 feet. Three of the walls had several large and small openings, including sliding doors and can delivery lines. The other was a restaurant; it measured about 50 by 100 feet. It also was of concrete. The only entrance faced on a busy thoroughfare.

For field use, the wooden plyboard panels were prepared in advance so that residues of appropriate age would be at hand as needed during the short time available. The panels were stored under conditions simulating as much as possible the two sets of field conditions. Chilled, marked flies, handled as noted above, were exposed to the chemicals by the method of Bruce (1949), modified to include two main resting surfaces, and released on the spot. Areas chosen for release were those determined by observation and questioning of plant personnel as being points of entry with nearby resting places. These spots were few, and the actual number of flies was always low. One hundred flies were released from each of the three points selected in the cannery. One hundred flies were released at a single point in the restaurant. This method of exposure and release in effect simulated spot spraying.

In the cannery, the problem of carrying out the experiment without contaminating the working lines was solved by releasing the flies during the prepack run only, when the plant was being readied for current operations. No experimental work was carried out during actual canning operations. There was no problem of contamination in the restaurant, since the building was closed. In both cases the buildings were available for short times only. Tests in the cannery were carried out in April of 1951 and 1952, and in the restaurant in March 1952. A 2-week period was involved in each instance.

After consideration of laboratory results, exposure periods of 1 and 20 minutes were chosen. The first was used to represent a very short period of time a fly might remain on a treated surface under actual field conditions. The second was picked after laboratory observations indicated that this was an average length

of time for a fly to stay in one spot before moving on. One concentration of the insecticide involved was used for exposures in both the cannery and restaurant.

Flies were marked and examined according to the technique of Dalmat (1950, 1952). There was no greater mortality among these flies than unstained checks. A set of flies with a different colored dye was released at each of the three points in the cannery; three differently colored sets were released at the single point in the restaurant. Dyes used included methylene blue chloride, safranin O, safranin bluish, acid fuchsin, carmine, victoria green, aniline yellow, chrome yellow, and primuline yellow.

The canning plant was divided into nine arbitrary zones in order to aid recovery of the flies. The distance from each point of release to the center of each zone was taken as the total flight distance for all flies recovered therein. The average of the possible maximum flight distances from the three points of liberation was 200 feet. The same method was used to determine flight distances to each of the seven rooms in the restaurant. The possible maximum flight distance was 75 feet.

Flies were recovered by searching the buildings thoroughly inside for dead flies, and by trapping. The traps were of a wire cone-type described by Bishopp (1930), but smaller in size. One trap was placed overhead in each of the nine collecting zones in the cannery and one as high as possible in each of the seven rooms in the restaurant. The traps were baited with 2 ounces of decomposed liver, 2 ounces of a fermented mixture of brown sugar and water. The traps were rebaited when a new series of flies was released. Flies were anesthetized every day in the traps, put in a holding jar, and taken to the laboratory. Both live and dead flies were examined in the laboratory. Live, trapped flies were released to holding cages for observations on longevity, which could indicate additional flight distances.

RESULTS.—Laboratory results quickly indicated that short-time exposures to the particular insecticides used gave no control of flight, with a single exception. The exception was DDT paint applied as a light coat; estimated average flight distances ranged from none to 38 feet for residues up to 9 months. The heavy coat of DDT-containing paint was less effective, the effectiveness extending, however, to 6 months. The longer exposures gave data that confirmed expectations of increased flight control.

Flies exposed 20 minutes to the residues aged to time noted and released in the cannery were first found dead or trapped at the following average number of feet from points of release: aldrin, 34 (4 month residue); allethrin, 51 feet (2 month residue); BHC, 18 feet (6 month residue); chlordane, 12 feet (4 month residue); DDT (in kerosene), 11 feet (6 month residue); DDT (in lacquer), 13 feet (1 week residue); DDT (light coat of paint), 17 feet (9 month residue); DDT (heavy coat of paint), 14 feet (4 month residue); dieldrin, 49 feet (4 month residue); ditolyl trichloroethane, 61 feet (3 month residue); methoxychlor, 67 feet (6 month residue); piperonyl butoxide-pyrethrum, 12 feet (2 month residue); pyrethrum, 14 feet (1 month residue); TDE, 30 feet (5 month residue); toxaphene, 67 feet (3 month residue).

Additional distances that living, trapped flies might have travelled are indicated in table 1. The same table gives the numbers of flies which gives an indication of amount and probability of the occurrence of contamination that might take place in such a situation.

Results of tests in the restaurant were similar to those in the cannery. Both sets of field data were comparable to those obtained in the laboratory.

DISCUSSION.—The control of the flight of fly populations inside buildings, with the object of preventing contamination of food-stuffs being processed, apparently is not possible where a short time exposure of 1 minute is involved. The exposure gave good flight control only with the light coat of paint containing 2.5 per cent DDT. The results in all other cases were unreliable and erratic. The "Spot Method," which in some ways is the equivalent to short exposures, is not considered to be worthy of use, especially in small establishments, such as restaurants; and especially in view of the many factors, mentioned below, which can easily lessen its effectiveness. It is felt that the results obtained with the light coat of DDT paint, especially at these exposures, are exceptional and should be disregarded, as a survey of the literature does not reveal correspondingly favorable data.

Table 1.—Number of flies alive in lots of 300 exposed 20 minutes to various insecticides and released in a cannery, and the estimated additional average flight distances.

Age of Residue in Months	Number of Flies Living After Day of Collection on Date Indicated and Estimated Additional Flight Distances					
	Day					
	1st	2nd	3rd	4th	5th	6th
	Estimated Flight Distance (feet)					
	200	400	600	800	1,000	1,200
	0.02 Per Cent Aldrin					
1						
2						
3						
4	3					
5	7	1	1			
6	29	16	3	1		
9	37	23	19	2		
12		66	53	20	8	
	0.1 Per Cent Allethrin					
1						
2	56	2				
3	4	5	17	3	3	
4	110	19	38	11	3	
5	24	28	16	2	8	
6	14	31	31	4	2	
9		22	48	23	11	
12		10	43	41	8	
	0.3 Per Cent BHC					
1						
2						
3						
4						
5						
6	27	1				
9	31	48	19	1		
12	6	37	42	2	3	
	2 Per Cent Chlordane					
1						
2						
3						
4	18	1				
5	40	12				
6	32	19	1			
9	17	49	12	4		
12	8	43	32	14	8	
	5 Per Cent DDT (kerosene base)					
1						
2						
3						
4						
5						
6						
9	8	1	1			
12	4	11	1	1		
	5 Per Cent DDT (lacquer base)					
1						
2						
3	6					
4	24	37	14			
5		81	30	13	4	
6		2	35	22	12	
9			27	28	5	
12			38	80	30	
	2.5 Per Cent DDT (light paint coat)					
1						
2						
3						
4						
5						
6						
9						
12	23	8	1			
	2.5 Per Cent DDT (heavy paint coat)					
1						
2						
3						
4						
5	26		3			
6	18	34	8	8		
9	7	28	30	16	2	
12		23	31	20	14	
	0.2 Per Cent Dieldrin					
1						
2						
3						
4						
5	17	23	1			
6	32	42	19	3		
9	10	27	36	20	7	
12		22	48	29	7	
	2 Per Cent Ditolyl Trichloroethane					
1						
2						
3	24	20	12	3		
4	18	47	35			
5	11	30	53	16	7	
6	7	18	44	29	3	
9		35	55	35	1	
12		20	42	31		
	5 Per Cent Methoxychlor					
1						
2						
3						
4						
5						
6	14	6	2			
9	7	48	22	10		
12		41	49	16	9	
	1.1 Per Cent Piperonyl Butoxide-Pyrethrum					
1						
2	3	3	2			
3	21	11		3		
4	10	39	27	18	4	
5	9	24	36	22		
6	17	30	57	19	22	
9		41	63	2	13	
12			49	66	14	10
	0.1 Per Cent Pyrethrum					
1	3	8				
2	31	16	7			
3	44	29	16	2		
4	30	49	25	13	7	

NUMBER OF FLIES LIVING AFTER DAY OF COLLECTION ON DATE INDICATED AND ESTIMATED ADDITIONAL FLIGHT DISTANCES

AGE OF RESIDUE IN MONTHS	Day 1st	2nd	3rd	4th	5th	6th
	Estimated Flight Distance (feet) 200	400	600	800	1,000	1,200
	0.1 Per Cent Pyrethrum					
5	16	34	45	21	4	
6	3	28	49	30	17	18
9	1	8	56	32	14	2
12		16	47	43	31	19
	5 Per Cent TDE					
1						
2						
3						
4						
5		1				
6	13	12	1		6	
9	95	18	14	2	2	
12	47	81	8	27	1	
	3 Per Cent Toxaphene					
1						
2						
3	14	3	8	2		
4	19		2			
5	21	8	11			
6	18	15	13	9	3	
9	31	23	7	6	12	
12	8	34	41	3	3	

Flight control may be had with a longer exposure, e.g., 20 minutes. Chemicals which gave control for more than 1 month were aldrin, BHC chlordane, DDT (in kerosene and paint bases), dieldrin, ditolyl trichoroethane, methoxychlor, and TDE.

In food processing establishments which which have a heavy work schedule during the summer months, when the insect problem may be most severe, the need for spraying as few times as possible is great. An insecticide which will give the desired control for periods longer than 1 month with one spraying is desirable. Of the chemicals listed above, only BHC, DDT, and methoxychlor could be considered to give complete flight control with one spraying for a 5-month period with an exposure of 20 minutes. The first two insecticides have not been recommended by official agencies for use in food establishments. Methoxychlor is considered, under field conditions, to be less effective than the two mentioned. Lindane might be used as it does not have all of the disadvantages of the parent compound.

In food establishments, such as a restaurant, where the work load is not concentrated in a set, seasonal period of time, insecticides which give shorter periods of effective flight control might be used.

In any of the above cases there may be failure to derive the maximum length of benefit from a single spraying, either spot or complete, especially in buildings such as canneries with many points of entry. Not only do multiple entrances allow more insects to enter, but also allow for some external climatic factors, such as temperature and humidity, to influence the flight of the flies, either toward or away from sprayed areas. The temperatures and humidity may also exert a degrading effect on the insecticidal residues. The internal environment itself of many processing plants is such that there may be extremes in temperature and humidity.

Fluctuations in the actual fly population in such a situation, where both external and internal environment vary, is common. Muma and Hixon (1949) point out that house fly numbers in cow barns vary directly with increases and decreases in mean temperature after chemical treatments had lost their efficiency. Holway *et al.* (1951) indicate that this variation also holds true for small buildings, such as shops and dwellings. In data not presented here, this movement of population was distinctly noted in the cannery, where flies left the south side, from which the cool summer prevailing winds blow.

Other factors influencing control of insects inside a processing plant are the type of foods in the establishment (for attracting large numbers of insects), how recently fed were the insects, attractiveness or repellency of the insecticides, and/or their adjuvants and solvents, the fumigating effect of the insecticides, the age of the deposit, and the number of flies (Dicke *et al.* 1952; Gains & Mistric 1951; Hadaway & Barlow 1952; Teotia & Dahm 1950). There may be changes in habits so that flies no longer tend to rest in the usual attractive parts of a building (Bruce & Decker 1950).

In connection with the protection of edible materials in food establishments by residual insecticides, there has appeared the occasional recommendation (e.g., Dove 1947) that treatment be applied to selected places, i.e., where the flies congregate, so that the dying insects would be

restricted to those particular areas. Such a procedure has also been recommended for fly control in dairy barns (Moore *et al.* 1951; Pimental *et al.* 1950).

The number of flies in the area is especially important when spot-spraying is practiced. Insecticidal deposits can be masked by deposits of fly excrement in the favored resting spots, thus lessening the effectiveness of the control chemical (Barrett 1952). When flies appear in numbers great enough for this to happen, it means that uncontrolled larval development is taking place in the vicinity. Laake *et al.* (1950) concluded that sanitation in and around dairy barns influenced the population density and the length of time test materials remained effective.

Barrett (1952) and Muma & Hixon (1949) point out that practical fly control can not be achieved on dairy farms without the use of sanitation. Here the flight distance is of not much importance, while it is in such food establishments as a cannery, where the presence of but few flies in processed food may be cause for legal action. In the latter instance sanitation is also important, since it has a direct bearing on the presence of flies.

Hansens (1950) points out that chlordane and dieldrin kill slowly and flies remain in dairy barns for long periods after exposure. In this particular study, it was found that this slowness of action, resulting in lack of flight control, was inherent in the insecticides tested, with the exception of the three already mentioned.

Observations of eight other canneries in this area revealed that each had at least one large opening and many smaller ones near processing lines. Openings with favored resting spots in the particular cannery used were from a few inches to 15 feet away from processing areas.

SUMMARY AND CONCLUSIONS.—Laboratory and field experiments with non-resistant flies exposed to 12 different insecticides aged 1 hour to 12 months were carried out in order to determine the effects of the chemicals on flight range. In the laboratory, the flies were subjected to two sets of exposures; 0.5, 1, and 2 minutes; and 10, 20, and 30 minutes. It was determined by detailed observation of non-exposed laboratory flies that they might spend 10 per cent of their lives in flight. The flight distances of exposed laboratory flies were then determined. In the field, marked flies were exposed for 1 minute and for 20 minutes in a cannery and in a restaurant under conditions simulating spot spraying. Spots where flies were found dead in both establishments indicated actual distances travelled from points of liberation. Flies were trapped, and those living beyond the day of capture indicated, by the length of life, additional possible flight distances. Laboratory and field results were similar. Under field conditions at least, BHC, DDT, and methoxychlor gave complete flight control for 5 months at the 20-minute length of exposure. DDT in a paint base gave exceptional control, although data in the literature indicates that this might be unusual. Flight control with the 1 minute exposure was distinctly erratic and less reliable than with the longer exposure period. Factors influencing the insecticidal control of flight of insects in a building are discussed.

The data indicate the residual or persistant insecticides are not substitutes for basic sanitation in or near a food processing plant nor can they be dependably used in conjunction with sanitation. With the possible exception of DDT, BHC, and methoxychlor, complete suppression of insect flight, so necessary where quality control of foods being processed is held at a high level, can not be had since the killing action of the insecticides tested is so physiologically slow and variable. Flies are able to travel some distance before eventual death and hence are able to become contaminants of foods in such plants as canneries, which often have processing lines and areas near exterior openings and favored fly resting places.

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Control of Mites in Clothes Moth Cultures

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At frequent intervals cultures of the webbing clothes moth, *Tineola biselliella* (Hum.), used for insecticide evaluation at the Ohio State University, have been reduced by the activities of a predacious mite. In the rearing technique, the moths were allowed to oviposit on a 4- by 8-inch piece of cat's fur held tightly against a screened portion of the cage containing them. Twice a week the eggs were brushed from the fur and placed on wool strips in the rearing jars. Most of the mite population was confined to the piece of fur used for moth oviposition and they attacked the egg stage.

After considerable rearing difficulty an attempt was made to control the mites with a 10-per cent dust of p-chlorophenyl p-chlorobenzene sulphonate.[1] One-half gram of the miticide was dusted on the fur strip and rubbed in by means of a camel's-hair brush. A gradual reduction of the mite population followed and after approximately 4 weeks, no mites could be found in the culture. Since the original treatment was made some re-infestation has occurred, which was controlled by additional applications of the dust. Frequent and continued use of the miticide has been found to reduce the number of eggs laid by the moths. Since only one or two treatments with the miticide are necessary to control the infestation, the effect on the moth is of little consequence compared to the reduction of the culture by the feeding of the mites. This is being reported with the hope it may be of help to others faced with a similar problem.

[1] Ovotran, a product of the Dow Chemical Co.

Corn Earworm Control on Long Island[1]

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The corn earworm, *Heliothis armigera* (Hbn.), is the most serious pest of sweet corn on Long Island, New York, where there are usually 3.5 generations each season. The infestation increases in intensity as the season progresses, with August and September being the critical periods. During these months it is mandatory for sweet corn growers to apply insecticides for earworm control in order to harvest a saleable crop.

Butler & Carruth (1949) reported that 4 to 5 applications of a 5 per cent DDT dust, applied at 3-day intervals commencing when 60 to 70 per cent of the ears showed silks and continuing until the silks withered, gave satisfactory control of the earworm under Long Island conditions. As the moth oviposits on the silk, it is necessary to maintain complete coverage of insecticide on the green silk at all times. Butler further pointed out that no oviposition occurred on the withered silks. This dusting program has been used successfully by commercial growers.

DUST EXPERIMENTS.—A high-clearance, 6-row, self-propelled duster was used in the dust experiments. One-quarter acre plots of the variety Magna Gold were replicated 3 times in randomized blocks.

Table 1.—Comparison of 3- and 2-day interval dust schedules for the control of the corn earworm. Long Island, N. Y., 1951.

TREATMENT	PER CENT EARS INFESTED
Untreated	55
5% DDT (Treated Aug. 4, 7, 10, 13)	8
5% DDT (Treated Aug. 4, 6, 8, 10, 12)	6
1% Parathion (Treated Aug. 4, 7, 10, 13)	9

Experiment 1.—In 1951 this experiment was designed to compare the recommended 4-application, 3-day interval dust schedule with a 5-application, 2-day interval schedule, using 5 per cent DDT dust applied at the rate of 50 pounds to the acre. A 1 per cent parathion dust was also included in the test, applied at the same rate, and following the dust schedule recommended by Carruth & Butler (1949). All first applications were applied on August 4 when 70 per cent of the ears showed silks. The results are given in table 1. There appeared to be no advantage in shortening the application interval to 2 days, and the 1 per cent parathion dust compared favorably with the 5 per cent DDT dust. Growers have been reluctant to use parathion due to the possible hazard to which the operator is exposed.

Table 2.—Comparison of effectiveness of isodrin and DDT dusts for control of the corn earworm. Long Island, N. Y., 1952.

TREATMENT[1]	PER CENT EARS INFESTED		
	Instars 1–3	Instars 4+	Total
Untreated	51	43	94
5% DDT	31	13	44
2% Isodrin	40	23	63

[1] Treated August 27, 29 and September 1.

Experiment 2.—In 1952 the new insecticide isodrin was compared with DDT in an experiment conducted during late August and early September when the weather was cold and wet. Plots received the first treatment on August 27 when 30 per cent of the ears showed silks. Rain on August 28 made it necessary to make the second application on the following day. More rain followed on August 30 and the third treatment was made on September 1. High winds and intermittent rains continued for the next 5 days and it was impossible to operate the duster in the plots. The results of the experiment are given in table 2. The schedule followed here was incomplete and unsatisfactory, especially for a cold damp period. The control achieved with DDT was poor but surprisingly effective under such adverse conditions. The infested ears were separated into those with first to third instar larvae and those with fourth instar or larger larvae. Counts were made on September 15 and because of the poor schedule and the time lapse involved from the date of the last application to the date

[1] Journal Paper No. 929, New York State Agricultural Experiment Station, Geneva.

the counts were taken, it is believed that the first-, second- and third-instar larvae entered the ears after the last application of September 1. Such being the case, the figures under the column "4th instar and larger" in table 2 give a more reliable indication of effectiveness of the insecticides. Observation of these figures indicates when most of the ineffectiveness in control occurred. The cool weather caused an increase in the incubation period of the eggs and carried hatching past the time when there was sufficient coverage of insecticide. This situation is often encountered commercially and indicates the need for considering temperature as the principal factor in determining treatment interval. In this case a 4 to 5 day schedule, continued until even the withered silks had received 1 or 2 applications, would have been necessary for adequate control.

SPRAY EXPERIMENTS.—Butler, using a high-clearance sprayer in the Hudson Valley area (Ulster County) in 1950[2] found that 3 applications of DDT (4 qts. of 25 per cent emulsion per acre) plus mineral oil (10 qts. per acre) at 5-day intervals gave satisfactory control of the earworm. However, this insect is a less serious pest here than on Long Island.

Experiment 1.—This experiment was conducted in 1951 to test the effectiveness of the 3-application, 5-day interval schedule as used in the Hudson Valley. Various concentrations of DDT and mineral oil were used. The spray was applied to 0.25-acre unreplicated plots at the rate of 25 gallons per acre, 80 p.s.i., using a high-clearance Iron Age Sprayer (10 rows—4 nozzles per row). The first application was made on August 13 when 60 per cent of the ears showed silks. The variety treated was Lee. The results of the experiment are given in table 3. As can be readily seen, none of the treatments gave a high degree of control. There appeared to be three factors responsible for this: (1) Apparently the spray interval was too long to maintain complete coverage of the growing silks; (2) The pressure and gallonage were too low causing ineffective coverage; (3) This variety, Lee, has long ears, loose husks, and a tendency to produce splayed ears which facilitated the entry of the larvae. These postulations were tested in the two following experiments.

Table 3.—Comparison of various DDT formulations applied with a high-clearance sprayer for the control of the corn earworm. Long Island, N. Y., 1951.

TREATMENT[1]	PER CENT EARS INFESTED
Untreated	85
DDT 1 qt. (25% emulsion)	57
DDT 2 qts. (25% emulsion)	68
DDT 3 qts. (25% emulsion)	46
DDT 1 qt.+10 qts. M. O.[2]	75
DDT 1 qt.+10 qts. M. O.[2]	76

[1] Treated August 13, 18 and 23.
[2] Mineral oil—*Kremol 70* (average viscosity 70° Saybolt).

Experiment 2.—In this and the following experiment, conducted in 1951, the applications were made with a hand sprayer using approximately 35 gallons per acre. Plots 100 feet long and 4 rows wide were replicated 3 times in randomized blocks. DDT (25 per cent emulsion) and mineral oil (*Kremol 70*) were used at various concentrations (Table 4). The first application was made on August 24 when 50 per cent of the ears showed silks and continued at 3-day intervals until September 30. The results of the experiment are given in table 4. The degree of control obtained here is comparable to that one might expect with a 5 per cent DDT dust. The role of mineral oil in this test is not clear. Under some circumstances oil apparently has some advantages, probably as a penetrant in aiding the insecticide to enter the silk channel and as an adherent during wet weather.

Table 4.—Results of hand sprayer test to compare three concentrations of DDT and mineral oil for the control of the corn earworm. Long Island, N. Y., 1951.

TREATMENT[1]	PER CENT EARS INFESTED
Untreated	60
DDT 1 qt. 25% emulsion	11
DDT 1 qt. 25% emulsion+10 qts. M. O.[2]	6
DDT 2 qts. 25% emulsion	3
DDT 3 qts. 25% emulsion	8
10 qts. M. O.[2]	9
7½ qts. M. O.[2]	21

[1] Treated August 24, 27, 30 and September 3.
[2] Mineral oil—*Kremol 70* (average viscosity 70° Saybolt).

Experiment 3.—This experiment was designed to test the importance of each

[3] Unpublished mimeographed report.

application in a 3-day interval, 3-application schedule. All applications contained 1.4 qts. of DDT (25 per cent emulsion) in 35 gallons of water per acre. The plots were replicated 3 times. The first application was made on August 24 when 50 per cent of the ears showed silks. The results of the experiment are given in table 5. It would appear that under these circumstances the second application was the most important of the three sprays applied. Furthermore, the control obtained with the first two sprays was as good as with three applications.

Table 5.—Hand sprayer test to determine proper timing of DDT sprays for control of the corn earworm. Long Island, N. Y., 1951.

Application Date, August			Per Cent Ears Infested
24	27	30	
Untreated			45
×			49
×	×		8
×	×	×	9
	×		16
	×	×	21

Since temperature and other weather conditions would vary considerably throughout the season, these results are of little value in indicating an adequate spray schedule. It is interesting to note that where the silks are covered adequately—as in these two hand sprayer tests—superior control can be obtained with a low concentration of DDT and a relatively flexible schedule. One must conclude that control ineffectiveness with commercial equipment must be largely one of poor coverage of the silks and not just poor timing of applications.

Experiment 4.—In 1952 a preliminary test was conducted on the effects of pressure, gallonage, and nozzle type. The same spray machine was used as in 1951, but a larger pump was installed to give pressure up to 150 p.s.i. Plots 230 feet long and 10 rows wide were replicated 3 times in a randomized block. All treated plots received four applications of 3 quarts of 25 per cent emulsion per acre on August 2, 4, 6, and 11, with the first application being made when 25 per cent of the ears showed silks. The variety of sweet corn was Golden Cross. Three types of spray nozzles producing 3 distinct spray patterns were tested: these were flat, disc, and cone nozzles producing flat or fan, hollow cone, and cone spray patterns, respectively.

The results are given in table 6. The differences in gallonage were unavoidable as the sprayer operated at only three set forward speeds. The sprayer was operated at a speed of 3 m.p.h. throughout the experiment. It is interesting to note that where comparisons can be made (120 lbs. pressure), there was little difference in the degree of control obtained with three types of nozzles. The cone type of nozzle is used commercially by Long Island growers. Cone and disc types of nozzles were compared at 80 and 120 p.s.i. pressure and both gave slightly better control when used at 120 p.s.i. pressure. The comparison of gallonage may only be made with the disc type of nozzle at 80 p.s.i. pressure. It would appear here that

Table 6.—Effects of nozzle, pressure and gallonage on the control of the corn earworm with DDT sprays. Long Island, N. Y., 1952.

Nozzle Type	Gals per Acre	Pressure p.s.i.	Per Cent Ears Infested
Untreated	—	—	65.3
Flat	24	80	13.0
Flat	40	120	9.0
Disc	28	80	16.3
Disc	52	80	5.6
Disc	56	80	9.0
Disc	54	120	6.6
Cone	48	120	5.3
Cone	60	80	9.7

L.S.D. between treatment means 5% level 18.1

the higher gallonage tested increased the control efficiency. This phase of the control program requires considerably more investigation under more exacting conditions and better experimental design.

Experiment 5.—Endrin and isodrin, which have shown promise for control of lepidopterous larvae, were tested in 1952. The 19 per cent emulsifiable concentrates containing 1.6 pounds of the actual toxicant per gallon were used at the rate of 1.5 pints in 50 gallons of water per acre. For comparison, 3 quarts DDT (25 per cent emulsion) and 3 quarts of DDT (25 per cent emulsion) plus 10 quarts of mineral oil applied at the same rate were used.

The experiment was divided into two parts, "A" and "B" which were conducted at different periods during the season

using the same make of machine. In both cases plots were replicated 3 times. The results of this experiment are given in table 7. As may be seen, in the earlier test, "A," the infestation was lower than in the "B" test. Isodrin and endrin compared favorably with DDT in test "A" but not in test "B." The weather at the time test "B" was conducted was wet and it is interesting to note that DDT plus mineral oil effected the best control. The wet weather may also account for the low effectiveness of isodrin and endrin in test "B."

Table 7.—Comparison of effectiveness of three insecticides used as sprays for control of the corn earworm. Long Island, N. Y., 1952.

Treatment	Per Cent Ears Infested	
	A[1]	B[2]
Untreated	24	65
DDT (3 qts. 25% em.)	8	15
DDT (3 qts. 25% em.)+ M. O. (10 qts.)	—	7
Endrin (1.5 pts. 19% em.)	10	23
Isodrin (1.5 pts. 19% em.)	4	36

[1] Pressure—140 p.s.i., 60 gals./acre 40 per cent ears in silk on July 7. Treated July 7, 11, and 15.
[2] Pressure—120 p.s.i., 50 gal./acre 25 per cent ears in silk on Aug. 2. Treated Aug. 2, 4, 6, and 11.

SUMMARY.—A report is given on tests conducted for corn earworm control under Long Island conditions in 1951 and 1952 using hand and power spraying and dusting equipment.

Four 5 per cent DDT dusts applied at 3-day intervals and five dusts applied at 2-day intervals gave good and equal control. One per cent parathion dusts gave similar results.

DDT and mineral oil sprays (3 quarts of 25 per cent emulsion) gave results about equal to dusting at same time interval but were unsatisfactory in a 3-spray 5-day interval program.

Endrin and isodrin gave promising results. Mineral oil increased the efficiency of DDT sprays, especially under cool, rainy conditions.

A preliminary check was made on the influence of nozzle-type (flat, disc and cone), pressure (80 and 120 pounds) and gallonage per acre (approximately 25 and 50 gallons). Better control was obtained with the higher gallonages; differences shown by the other variables were small and not significant.

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Hatching of Indian-Meal Moth Eggs in Glycerine

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During July 1951 the junior author found small larvae of Phycitidae (determined by H. W. Capps) in open dishes containing glycerine exposed in a prune warehouse in San Jose, Calif. The dishes had been distributed for the purpose of accumulating samples of air-borne materials. When some of the containers were examined, evidence was found that moths had been caught in the glycerine, had voided eggs during their final struggles to escape, and that some of the eggs had hatched.

In order to confirm this evidence, the senior author put newly laid eggs of the Indian-meal moth, *Plodia interpunctella* (Hbn.), in dishes containing glycerine. After the dishes had been incubated at 80° to 88° F. for 4 or 5 days, two newly hatched larvae and several larvae that were still within the egg shells were present. Eggs on raisins were used as checks. Nearly all of them hatched. Other eggs placed in glycerine on Sept. 5, 1951, and incubated for 5 days at room temperatures produced one hatched larva, and about one-third of the embryos developed fully but failed to hatch.

In another test, run at room temperatures for 6 days in September, newly laid eggs of the Indian-meal moth were scattered on the surface of dishes containing glycerine, equal parts of glycerine and water, or water alone. From 50 to 75 eggs were used in each container. Eggs dropped on water sank immediately, and none hatched or developed during an observation period of 6 days. In glycerine or glycerine and water the eggs remained suspended just beneath the surface. In the dish containing glycerine and water two larvae hatched and about one-fifth of the eggs contained fully developed larvae.

All hatched larvae found were dead. In general 1.5 to 2 per cent of the eggs hatched in glycerine or in a mixture of glycerine and water. One-fifth to one-third of the embryos developed to the point of hatching.

The information given above has no immediate application to control measures, but the unexpected behavior of Indian-meal moth eggs immersed in glycerine may be useful in future experiments.

Mortalities of *Sphenarium purpurascens* Charp. (Acrididae) as Related to Lengths of Exposure to Some Insecticides[1]

G. Mallory Boush

During the late summer of 1952 a number of serious outbreaks of grasshoppers occurred in Mexico, particularly in the coastal and southern regions. To determine control measures suitable to Mexican conditions, replicated field experiments utilizing the more commonly known organic insecticides were performed. The tests were conducted on corn in the silk stage near Tlalnepantla, in the State of Mexico.

The grasshopper infestation consisted almost entirely of adults of the species *Sphenarium purpurascens* Charp.,[2] a yearly pest in the Central Mesa of Mexico. From the appearance of the defoliated weeds and grass stubble on the edges of fields and ditches, it was thought that the grasshoppers migrated into the fields in search of additional food.

Field Tests.—A portion of a cornfield, heavily and rather uniformly infested, was used as the test area. Each experiment took the form of a randomized block, replicated 5 times, and each of the treated areas contained nine rows, 92 centimeters apart and 20 meters long. Relatively small plots such as these could be employed because this species of grasshopper is unable to fly and has slow and sluggish habits. The degree of infestation was determined by counting the total number of grasshoppers on 10 hills of corn in the center row of each plot, each hill consisting of two or three plants. In general, the infestation averaged about 300 to 350 grasshoppers on the plants in the 10 hills.

To determine the effectiveness of the materials being tested, three counts were made in each plot: the first just prior to application of the insecticides, and the second and third 12 and 24 hours, respectively, following application. The relative effectiveness of the different insecticides was determined by the difference between the pre-treatment and post-treatment counts. The insecticides and the concentrations used are shown in table 1. Six of the materials were applied as dusts with a rotary hand duster at rates of 30 to 38 pounds per acre. The other two, endrin

[1] Journal Series Paper No. 8 of The Mexican Agricultural Program of The Rockefeller Foundation.
[2] The author wishes to express his appreciation to A. B. Gurney, Bureau of Entomology and Plant Quarantine, Washington, D. C., who identified this grasshopper.

Table 1.—Effectiveness of certain organic insecticides against grasshoppers on corn in Mexico, 1952.

Insecticides and Concentrations	Active Ingredient per Acre (Pounds)	Per Cent Mortality[1] After[2]			
		12 Hrs.		24 Hrs.	
		Range	Mean	Range	Mean
Dieldrin 1.0%	0.35	68–80	74.2	96–100	98.2
Dieldrin 2.5%	0.88	87–93	89.8	99–100	99.8
Aldrin 1.0%	0.32	69–88	77.8	95–100	97.8
Aldrin 2.5%	0.82	83–96	88.6	99–100	99.6
BHC 1.0%	0.36	78–92	86.6	90– 97	94.2
BHC 2.5%	0.85	89–98	93.0	93–100	97.0
Isodrin 0.5%[3]	0.43	81–92	83.2	80– 96	91.4
Parathion 0.5%	0.16	36–51	43.6	61– 80	69.4
Parathion 1.0%	0.35	59–80	66.8	69– 84	76.0
Toxaphene 5.0%	1.74	18–36	26.8	46– 60	53.0
Toxaphene 10.0%	3.60	36–47	40.4	55– 69	61.4
Chlordane 2.5%	0.95	27–39	32.0	41– 54	46.6
Chlordane 5.0%	1.80	39–62	49.6	50– 77	63.8
Endrin 0.5%[3]	0.36	24–40	32.8	43– 59	47.6

[1] Based on difference between pre-treatment and post-treatment counts.
[2] A heavy rain (about 2.5 inches) fell approximately 3 hours after application of the insecticides.
[3] Applied as sprays; all others applied as dusts.

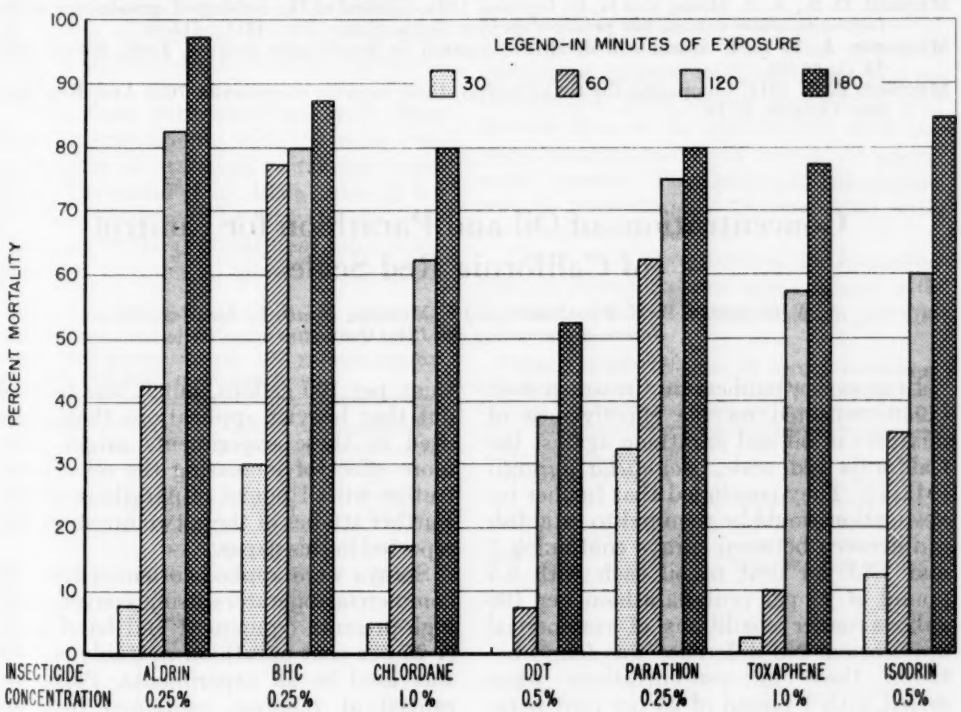
and isodrin, were applied as sprays with a 2-gallon (U.S.) knapsack sprayer at rates of 36 and 43 gallons per acre, respectively.

The growing season and the rainy season occur simultaneously in Mexico (June through September). During this season heavy rains often occur almost every afternoon. Three hours following application of the insecticides in this experiment, a rainfall of approximately 2.5 inches occurred. This deluge appeared to remove the insecticide deposits completely from the plants. In spite of the short period of exposure, some of the treatments appeared to have given control. Therefore, instead of abandoning the experiment, post-application counts were made. The results are shown in table 1. In this test, on the basis of both the 12- and 24-hour counts, BHC at both concentrations, aldrin and dieldrin at the 2.5 per cent level, and isodrin, gave effective control. However, chlordane and toxaphene, two materials in general use for grasshopper control, gave poor results under these rather severe conditions.

The following day no rain fell and the experiment was repeated in the same field but in an area which had not been previously treated. All the insecticides except two gave mortalities greater than 90 per cent. The exceptions were the 0.5 per cent concentrations of parathion and endrin. This would indicate that materials satisfactory for grasshopper control under ideal conditions vary considerably in effectiveness under conditions where the length of exposure is reduced. This factor could be quite important in grasshopper control in tropical and subtropical areas of the world where heavy rainfalls occur daily.

LABORATORY TESTS.—Further tests were conducted in the laboratory at Chapingo to obtain additional data on the relationship between exposure time and grasshopper mortality. The technique used was developed by Morrison (1945) for the evaluation of organic insecticides for contact action, but was modified in our experiments by varying the length of time the test insects were exposed to the insecticides. Briefly, this method involves dipping filter papers individually into insecticide solutions of known concentrations. When the filter papers are dry, the

Table 2.—Relationship between lengths of exposure to various organic insecticides and insect mortality, as indicated in laboratory tests.



insects under study are exposed to the insecticidal residue and the number of insects dead at the end of 24 hours is recorded.

In the four tests the results of which are shown in table 2, the treated filter papers, 25 centimeters in diameter, were allowed to dry for 16 hours. Then a round cage, 20 centimeters in diameter and 40 centimeters high, constructed of cellulose acetate with a muslin top, was placed over the papers. Ten adult female grasshoppers of the same species, *S. purpurascens*, were placed inside each cage. For food, a small quantity of alfalfa in a vial of water was placed in each cage. Each of the treatments in a given test was replicated 4 times. To insure contact of the grasshoppers with the treated papers, the cages were occasionally jarred.

In the first of the four tests the treated papers, along with an untreated check, were left under the cages for 30 minutes, after which they were removed and replaced by clean untreated filter papers. The other three tests were similarly conducted, except that the papers were left under the cages for 60, 120, and 180 minutes, respectively. These exposure periods were selected because preliminary tests had shown that exposures shorter than 30 minutes resulted in little or no mortality, and exposures longer than 180 minutes gave high but almost identical mortalities.

Table 2 shows that BHC and parathion at the shorter exposures of 30 and 60 minutes gave the highest mortality of the materials tested. At these shorter periods of exposure chlordane, DDT, and toxaphene gave low mortalities. In the third and fourth tests of 120 and 180 minutes' exposure, respectively, the materials tend to equalize, producing more nearly the same general mortalities. Aldrin, in both of the later two tests, produced the highest mortalities. Whereas the results with parathion in the field indicated a rather low degree of toxicity, the laboratory tests produced a much higher mortality. This inconsistency is noted but the explanation is unknown.

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Concentrations of Oil and Parathion for Control of California Red Scale

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In an earlier publication Cressman *et al.* (1950) reported on the effectiveness of mixtures of oil and parathion against the California red scale, *Aonidiella aurantii* (Mask.). They concluded that further investigation would be required to establish a difference between sprays containing 1 and 1.75 per cent of oil each with 0.5 pound of 25 per cent parathion per 100 gallons under conditions of commercial application. No difference was found between these oil concentrations when mixed with 1 pound of 25 per cent parathion per 100 gallons, but it was pointed out that heavier applications than those used in these experiments might show more effect of increasing the oil concentration with 1 pound of parathion added. Further studies of these two questions are reported in this paper.

Sprays were applied to lemon trees by commercial operators using conventional high-pressure equipment and hand guns. A 25 per cent parathion wettable powder was used in all experiments. Plots, arranged at random, contained from 23

to 62 trees each. Ten trees were selected for uniformity of size and condition in each plot and were used for both pretreatment and posttreatment counts of scale infestation. Effectiveness was judged by the change in infestation after there had been time for at least the major part of a year's buildup. Methods of estimating infestations were similar to those described by Cressman and Broadbent (1944). Pretreatment counts of adult females were made on gray wood, posttreatment on green or intermediate wood. Either 3- or 6-inch pieces were examined, depending on the average level of infestation in a plot.

Sprays containing 1 and 1.8 per cent of medium emulsive oil with 0.5 pound of 25 per cent parathion per 100 gallons were applied in two lemon groves near San Fernando, Calif. Three plots were treated with each mixture in both groves. Grove No. 1 was sprayed on May 22, 1951. Pretreatment infestations ranged from 1.1 to 16.2 live adult females per 3-inch piece of branch. Posttreatment infestation on green wood was estimated the following March. Grove No. 2 was sprayed on March 29, 1952. Pretreatment infestation was more uniform, ranging from 4.6 to 6.9 scales per piece of branch. Posttreatment infestation was measured on intermediate wood in October 1952. Results are shown in table 1.

These data were combined with those from the experiments with the same concentrations of materials previously published (Cressman *et al.* 1950, table 2) for statistical analysis. The ratios of the posttreatment to the pretreatment infestation were used in order to allow for the effect of the large variation in pretreatment infestation within grove No. 1. The difference between the two oil concentrations was highly significant. In grove No. 2, and in the experiments previously reported the posttreatment infestation after the spraying with 1 per cent oil was about twice that with 1.8 per cent. In grove No. 1 the spray application became uneven after the first plot was treated with 1.8 per cent oil plus parathion, and there was little difference in the effectiveness of the two concentrations of oil in the remaining five plots. Other sprays in which less detailed data were taken have also indicated the need for thorough coverage in order to obtain the benefit of the higher oil concentration with parathion.

Experiments were conducted in another grove to make further comparisons of the two concentrations of oil each containing 1 pound of 25 per cent parathion per 100 gallons. Plots treated with 1.8 per cent oil containing 0.5 pound of the parathion were also included. A special light oil having the following specifications was used:

Viscosity (100° F.)	51 seconds Saybolt
Unsulfonatable residue	91 per cent
Distillation	84 per cent at 636° F.

It was made emulsive with 0.5 per cent of glyceryl monooleate. Two plots of lemon trees were sprayed with each material on October 11, 1950. Spray application was heavier than in the experiments with the same concentrations of materials previously reported. Posttreatment infestation records were made in October 1951 with results shown in table 2.

There was no difference between the two oil concentrations when mixed with 1 pound of 25 per cent parathion per 100

Table 1.—Effectiveness of sprays containing 1 and 1.8 per cent of oil each with 0.5 pound of 25 per cent parathion per 100 gallons against California red scale on lemon trees.

Number of Scales per Unit		Ratio of Posttreatment to Pretreatment	
Grove No. 1	Grove No. 2	Grove No. 1	Grove No. 2
1 Per Cent Oil			
1.37	2.98	0.24	0.54
.52	3.01	.31	.49
.43	3.49	.39	.46
1.8 Per Cent Oil			
1.50	1.19	.09	.17
1.11	1.48	.24	.23
.50	1.51	.38	.33

Table 2.—Effectiveness of sprays containing indicated concentrations of oil with parathion against California red scale on lemon trees.

Materials per 100 Gallons of Spray		Scales per Unit (Number)	Ratio of Posttreatment to Pretreatment
Oil (Per Cent)	Parathion 25 Per Cent (Pounds)		
1.8	0.5	1.79	2.06
		2.60	2.14
1.0	1.0	1.42	.76
		1.74	1.14
1.8	1.0	1.39	.84
		1.23	1.17

gallons. The posttreatment increase in infestation was about half that in the plots treated with 1.8 per cent oil plus 0.5 pound parathion, a significant difference. The results were very similar to those obtained with a somewhat lighter application and published earlier (Cressman *et al.* 1950).

Thoroughness of the spraying in these experiments was shown by a mortality count made 3 months afterward, in which only 1 survivor was found in 2,400 scales. Evidently the toxicity of the two more effective mixtures was great enough, so that spray coverage was the limiting factor in survival even with heavy applications. The results indicate that commercial control of California red scales is not likely to be improved by increasing the oil concentration above 1 per cent when 1 pound of 25 per cent parathion is used in 100 gallons of spray.

EFFECT ON OTHER INSECTS.—Infestations of the citrus red mite, *Paratetranychus citri* (McG.), became heavy in grove No. 2 during the summer following the spray application. Leaf samples from 10 trees in each plot were taken at intervals and the number of mites was estimated according to the procedure described by Henderson & McBurnie (1943). The average numbers of mites per leaf, after being sprayed with oil plus 0.5 pound of 25 per cent parathion per 100 gallons, were as follows:

Per Cent of Oil	*July 1*	*July 21*	*Aug. 13*
1.8	2	3	10
1.0	6	7	18

Infestation was significantly heavier in the plots treated with 1 per cent oil with parathion. Mites never became numerous in grove No. 1. In the grove treated in October 1950, a heavy infestation developed by the following May, with little or no variation that was related to treatment. No other pests reached significant numbers.

TREE REACTIONS.—The part of grove No. 1 that was not used for experimental plots was also sprayed on May 22, 1951 with 2 per cent medium emulsive oil. The alkanolamine salt of 2,4-D at 6 p.p.m., acid equivalent, was added to part of the sprays containing 1.8 per cent oil with parathion. The soil was dry when the sprays were applied and irrigation was not started until 2 weeks later. Under these conditions there was considerable early drop of leaves. The drop was greatest in the parts treated with the oil containing parathion without 2,4-D, and least where 2,4-D was used. While the drop stopped soon after irrigation was started and did not amount to commercial damage, its occurrence emphasizes the importance of adequate soil moisture when oil with parathion is being applied to citrus trees. No adverse tree reactions occurred in any of the other groves.

SUMMARY.—Sprays containing 1.8 per cent of oil with 0.5 pound of 25 per cent parathion per 100 gallons when thoroughly applied were more effective against California red scale, *Aonidiella aurantii* (Mask.), than 1 per cent of oil with parathion. With less uniform coverage there was little difference in the effectiveness of the two concentrations of oil with parathion.

Sprays containing 1 per cent of oil with 1 pound of 25 per cent parathion were just as effective as those containing 1.8 per cent oil with 1 pound of parathion when a heavy application was made. Both mixtures were better than one containing 1.8 per cent oil with 0.5 pound of 25 per cent parathion.

In one grove this last mixture gave better control of the citrus red mite, *Paratetranychus citri* (McG.), than 1 per cent oil containing 0.5 pound parathion.

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Life History of *Hylemya lupini* (Coq.) in Florida[1]

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Blue lupine, a winter legume produced primarily as a green manure crop, has been grown extensively in the coastal plains of the Southeast since the early 1940's. The acreage devoted to this crop has declined in recent years, but it still remains the most important winter legume in this section. Fields planted in October make a rapid growth during the fall and winter months. When the crop is turned under in February, preceding a crop of corn, the green weight often exceeds 20,000 pounds per acre. If the crop is grown for seed production, it is combined in May. Seed yields of 1000 pounds per acre are common.

First evidence of extensive insect damage in the South occurred in 1945 in the vicinity of Quincy, Florida (Decker & Bond 1946), when anthomyiid larvae were found burrowing in the stems of plants in considerable numbers. Specimens sent to the Bureau of Entomology and Plant Quarantine were identified as *Hylemya lupini* (Coq.). The lupine fly has now become the most important insect attacking lupine in the coastal plains. It is becoming so destructive in some areas that it threatens the future of the crop.

The species, thought to be a native insect, was originally described as *Phorbia lupini* by Coquillette (1901). The first report of damage by this insect was made by Fowler (1902), who noticed it in experimental lupine plantings in California. He gave a brief description of the damage caused by the larvae and made observations on the duration of the stages. Chittenden (1908) related their importance in the control of loco weeds and briefly described the damage to these plants. Further investigations on the distribution and damage in Florida were reported by Bond & Decker (1947).

Distribution and Plants Attacked.—The lupine fly has been recorded from the following states: Alabama, Florida, Georgia, South Carolina, Kansas, New Mexico, Texas, Colorado, Arizona, Washington, Oregon, and California (Dorward 1953).[3] In the lupine-growing area of the Southeast, its distribution on the north is roughly bordered by a line drawn through Montgomery, Alabama, and Tifton, Georgia, and it extends as far south as Gainesville, Florida. A recent survey conducted in Florida showed that it is present in nearly all of the lupine-growing counties in the state. General observations from various sources indicate that it is also present in most of the lupine-growing counties of Alabama and Georgia.

The lupine fly is reported to attack the following species of *Lupinus: albus, angustifolia, termis, cosentini, pilosus,* and *arborea* (Strubenrauch 1904). It does not survive on *L. leuteus,* although it does deposit eggs on this plant. It has been found attacking the loco weed, *Astragalus mollissimus* (Chittenden 1908).

Types of Injury.—The effects of injury to the lupine plant may be of several kinds depending on the stage of growth of the plant. Newly hatched larvae usually bore into the plant at the terminal or the lateral bud, but occasionally at the leaf bract or at the junction of lateral stems with the main stalk. The point of entry can readily be recognized by the withered condition of the distal portion of the stem and the brownish frass which covers the entrance to the burrow. The infested buds wilt, and the top of the bud takes on a blackish appearance which can be easily seen from some distance.

As the plant increases in size, the injured bud becomes surrounded by vigorous, upright adventitious stems, a condition especially characteristic of fall injury (Fig. 1). During the flowering stage the larvae bore into the axis of the developing racemes, causing a reduction in seed yield. Late in the season the larvae occasionally tunnel into the developing seed pod, causing the pod to rot and retarding seed development. In the loco weed the larvae burrow into the underground parts of the plant, but this has not been observed on lupine. During the fall the fly confines its attack in large fields to the plants nearest the borders of the field.

Plants attacked at an early stage of development and not killed, largely out-

[1] Florida Agricultural Experiment Station Journal Series, No. 180.

[2] The author is indebted to Dr. L. C. Kuitert for assistance in the preparation of this manuscript.

[3] Personal communication from Kelvin Dorward, U. S. Bureau of Entomology and Plant Quarantine.

FIG. 1.—Lupine plants: normal (left); attacked by larva of *Hylemya lupini* (right). Note adventitious branches arising below point of attack.

grow the injury during the winter months and produce about 75 per cent as much green weight as uninfested plants. The loss in green weight caused by the spring infestation appears to be negligible. When young plants do not get a good start before cold weather, the plant growth is greatly reduced by larval injury, and the crop may be considered a failure. The exact amount of loss in seed production has not been determined, but an estimate of 25 per cent reduction in seed yield for the state of Florida seems to be a reasonable approximation.

DESCRIPTION OF STAGES.—The egg is elongate, 1.1 mm. long by 0.4 mm. wide. It is white in color and sculptured with minute spines which probably serve as an aid in attachment. Eggs are deposited singly when adult population is low, but ten or more eggs may be found in a group when deposition becomes heavy. The egg is deposited in a variety of places but usually is pushed into the terminal or lateral bud in such a manner that it cannot be readily seen unless the bud is opened. They may also be deposited on the leaf bract, stem, or junction of the stem with the main stalk and can be found at almost any stage of plant growth.

The whitish larva is 0.9 mm. in length when it first emerges and grows to a length of 6 mm. It is typically muscoid in appearance and may be distinguished from closely related species by the 14 fleshy tubercules arranged around the spiracles on the terminal segment and the 11 spiracles on each side of the prothoracic segment. The newly hatched larva feeds for a few hours on the tender bud and then bores into the stem, remaining close to the growing point for the first several

days. It then tunnels from 3 to 6 inches into the stem for further development, migrates frequently within the tunnel, and returns occasionally to the distal end of the burrow. The initial entry hole becomes covered with brown frass which dries and hardens. Usually only one larva is found in a burrow, but two or three larvae are sometimes seen. In a heavy infestation one larva is found within each lateral stem, and more than 100 larvae have been found infesting a single plant.

The coarctate pupa is brown in color, and about 4 mm. long by 1.5 mm. wide. It is usually found in the ground near the base of the plant, but occasionally in the larval tunnel near the point of entry. Observations on 144 pupae showed that the depth of pupation ranged from 0.5 to 6 inches, depending on the soil type. In the sandy soils of Florida they are usually found in the upper 2 inches.

The adult of *Hylemya lupini* resembles that of *H. cilicrura* (Rond.) but is slightly larger and may be distinguished by the long hairs on the under side of the femora. It is quite active and is found on or near the host plants during its entire life. It withstands temperatures of 24° F. for 24 hours without appreciable loss of vigor and short exposures to temperatures over 90° F. without excessive mortality, although activity is appreciably retarded. Examination of 100 flies showed the sexes to be equal in number.

DURATION OF STAGES.—*Egg.*—The incubation period was observed in the field, in an unheated greenhouse, and in the laboratory. The temperature was quite variable and is reported as the average daily temperature for the period of observation. In the field, plants were tagged daily as eggs were deposited on them; if another egg was found later in the vicinity of the tagged egg, the plant was abandoned. These plants were then observed daily to determine the incubation periods. In the greenhouse, in conjunction with egg-laying studies, plants on which eggs were found were isolated, all but one egg was removed from the plant, and the incubation period was determined. In the laboratory, eggs were carefully removed from plants, placed on moistened pieces of filter paper in petri dishes, and examined daily for eclosion. Results of the tests are recorded in table 1.

The incubation period varies from 1 to 8 days, depending on the temperature. During the periods of the year when the majority of eggs are present, the incubation period is probably from 2 to 4 days. The effects of relative humidity have not been determined closely, but high humidity appears to favor development.

Table 1.—Duration of various stages of *Hylemya lupini* at various locations and temperatures.

Stage	No. Observed	Location	Mean Air Temp. (°F.)	Duration of Stages (Days)	
				Average	Range
Egg	25	Field	57	4.0	2–8
	39	Greenhouse	66	2.8	1–6
	18	Greenhouse	72	2.4	1–4
	53	Laboratory	70	2.5	1–4
	68	Laboratory	75	2.0	1–3
Larva	27	Unheated room	60	19.4	17–22
	29	Laboratory	70	12.4	10–16
	53	Greenhouse	74	17.2	12–24
Pupa	55	Laboratory	70	15.5	10–20
	17	Incubator	80	16.1	15–18
	36	Outdoor insectary	67	17.5	14–20
	13	Outdoors, 6 in. in ground	67	18.6	18–19
	25	Outdoors, 4 in. in ground	67	18.5	16–21
	23	Outdoors, 2 in. in ground	67	18.3	17–20
	20	Outdoor insectary	56	31.3	28–39
	47	Outdoors, 2 in. in ground	57	38.5	38–41

Larva.—The rate of development of the larval stage on blue lupines was determined in an unheated room, greenhouse, and laboratory as described previously. Newly hatched larvae were carefully placed on the buds of uninfested plants and were examined daily until the larvae had crawled from the plant and pupated. The results of these tests are also shown in table 1. The larval development is markedly slower than might be expected from comparison with other closely related species. At the apparent optimum temperature, the average length of the larval period is nearly 2 weeks, which is somewhat atypical of anthomyiids. It requires about 3 weeks to complete larval development at the lower temperatures, and high temperatures may retard development to some extent.

Pupa.—Since no attempt was made to ascertain the prepupal stage, it is included with the pupal stage. Large larvae which were judged nearly ready to pupate were brought into the laboratory and exposed to the various conditions as they pupated. In one set of experiments, the pupae were placed in petri dishes and kept in the laboratory, incubator, and outdoor insectary. In another series, the pupae

were placed under cages at various depths in the soil, and observations were made daily for adult emergence. The results of these tests are also shown in table 1. Not included in these data are three flies which required 4 months for pupation, 2 months in the laboratory and 2 additional months outdoors.

At temperatures of about 70° F., the pupae require about 2 weeks for development, but when subjected to temperatures below 60° F., the pupal period is a month or longer. Introduction of the pupae into the soil at various levels had little effect on the total length of pupation, at least at the higher temperatures.

Adult.—Experiments with adults were conducted throughout the fall, winter, and spring months in an unheated greenhouse. Newly emerged male and female adults were paired, introduced into cylindrical wire cages placed over potted lupine plants, and provided with milk-soaked cotton daily. Observations were made daily to determine the longevity of the sexes, the length of the pre-oviposition and oviposition periods, and the number of eggs laid per female. When eggs were found, the cage and flies were removed and placed over uninfested plants. When male flies died before female flies, another male was introduced. It was found that practically all egg laying occurred during daylight hours. The usual number of eggs laid during a 24-hour period was from 4 to 6; the maximum number observed was 13. No attempt was made to correlate adult activity or egg laying with temperature. However, it was noted that egg laying occurred between 55° and 95° F., with the maximum between 65° and 75° F.

The fecundity of the lupine fly is fairly low in the laboratory. The average number of eggs laid was 45, and the highest was 114. The longevity of the female ranged from 4 to 46 days and averaged 27 days, which was twice that of the male. The pre-oviposition period ranged from 4 to 14 days, and averaged about 7 days.

SEASONAL ACTIVITY.—During the 1952–1953 season, extensive data were collected on the relative abundance of all stages. At approximately monthly intervals 100 lupine plants were dissected, and the stages of development of the insects were determined. In cases where infestation was fairly recent and no larvae could be found, it was assumed that the larva had crawled off the plant and pupated in the ground. These data are presented below in the form of a general account of the seasonal activity on lupine.

The fall infestation caused extensive damage to early planted lupine, but little damage to lupine planted after mid-November. The adult fly was first seen in appreciable numbers in early fall. Larvae from this brood completed their development and pupated in late October and early November. A few of these pupae emerged as adults and laid eggs for a small late fall and winter brood of larvae, but most of the fall generation pupae overwintered. During a period of warm weather in late January and early February, the adult flies began emerging and laying eggs for the early spring generation. Most of these larvae completed their development before the lupines were turned under in late February and early March, and by mid-March another brood of flies emerged. This brood laid eggs on plants retained for seed production. The larvae completed development by mid-April, and some adults emerged in early May. By this time the plants were mature and no longer attractive for egg laying. The stage in which this insect passes the summer is not known, but the two best possibilities seem to be that a summer generation occurs on another host, or that pupae spend the summer in the ground.

NATURAL ENEMIES.—The lupine fly is relatively free from natural enemies. In heavily infested fields in the spring, several species of predatory spiders were present, and one of these, *Tetragnatha laboriosa* Hentz, appeared to be of special importance as a predator of the adult. A braconid, identified by B. D. Burks as *Bubekia* sp. is a parasite of the larva or pupa.

SUMMARY.—A preliminary account of the life history of *Hylemya lupini* (Coq.) on blue lupine in Florida is presented. This insect, now the most important insect pest attacking lupine in the Southeast, is distributed throughout most of the lupine growing areas. Lupine seedlings attacked early may be killed, and plants which recover from early infestation are appreciably reduced in green weight.

Data are presented on duration of the various immature stages, longevity of adults, length of pre-oviposition and oviposition periods, and number of eggs

laid per female. The length of time required to pass from egg to egg under laboratory conditions was about 37 days. The average number of eggs laid per female was 45, but the maximum was 114. Three generations and a partial fourth were observed on lupine during the crop season. The stage in which the summer is passed is not known.

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Effects of Narrow-Cut Petroleum Fractions of Naphthenic and Paraffinic Composition on Leaf Drop and Fruit Juice Quality of Citrus[1]

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The dropping of green leaves from citrus trees, without evidence of tissue damage, has frequently been reported as a result of the unfavorable reaction of the trees to the application of petroleum oils. Leaf drop of this type was noted in connection with the use of petroleum distillates in California as early as 1900. However, foliage "burn" (dead tissue areas) following application of these materials was of much greater concern.

In 1915–16, Gray & deOng (1926) showed that the hydrocarbons which could be removed from petroleum oil by treatment with sulfuric acid were largely responsible for foliage "burn." At that time premixed emulsion formulations were much more stable than those in use today, however, and proprietary emulsions containing approximately 80 per cent oil were used in spray mixtures at the rate of 10 to 13 per cent. Thus the additional cost of the acid refining process presented a limiting economic factor in the use of spray oils. The development of the quick-breaking emulsion principle (deOng *et al.* 1927) overcame this obstacle. After the announcement of these results, a large number of proprietary emulsions were placed on the market, most of them with little if any investigation of their insecticidal efficiency or of their effect on citrus trees. No standards were available for classifying the petroleum fraction employed in any given emulsion. Similar terms were used to describe oils with quite different properties. Considerable variation in pest control and damage to citrus orchards occurred with oil sprays, and, for lack of a reliable reference point, the situation became confused.

As this situation developed, Smith (1932) conducted extensive investigations of the factors involved in the use of oil sprays to control California red scale, *Aonidiella aurantii* (Mask.), and other pests of citrus in southern California. As a part of these studies, experiments were established to evaluate the relation of the properties of petroleum fractions to the effect of the oils on citrus trees. The number of leaves dropping from the tree in a prescribed period following application of the spray was selected as the measure of the adverse effect of the oil spray mixture on the tree. Smith found that the amount of leaf drop was related to the "weight"

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of the petroleum oil, as indicated by the fractional distillation range, and to the quantity of oil deposited on the foliage by the spray mixture.

Since the adoption of standards for five grades of foliage spray oils in California in 1932 (Erb 1932; Marshall 1932), the relative tolerance of citrus trees to petroleum spray oils, with respect to both variety and locality differences, has been estimated largely by the amount of leaf drop following application.

Brock (1929) observed that when oil sprays were applied to trees that were in need of water, the amount of leaf drop was greater than when applications followed irrigation. This is in direct contrast to the response noted in fumigation with HCN.

Leaf drop due to the application of spray oil may be effectively counteracted by the addition of very small amounts of 2,4-dichlorophenoxy-acetic acid to the oil spray mixture (Stewart *et al.* 1952).

Recently, the potential reduction of the total percentage of soluble solids of the juice of fruit from citrus trees sprayed with oil for pest control has assumed increased economic importance through utilization of larger volumes of fruit for juice concentrates. Yothers & McBride (1929), in Florida, Sinclair *et al.* (1941), in California, and Stofberg & Anderssen (1949), in South Africa, have found that oranges from trees fumigated with HCN, or left untreated, in most instances contained higher percentages of total soluble solids than comparable fruit from oil-sprayed trees.

In spite of the above considerations, petroleum oil offers certain advantages as an insecticide for citrus pest control. Several species of scale insects and of mites can be controlled with oil, often with the same application; as a result, spray oils have been the most efficient material per unit cost. In general, spray oils are relatively free of toxicity to man and warm-blooded animals and do not leave residues that constitute a toxic hazard to beneficial insect parasites and predators of citrus pests. An increase in the insecticidal efficiency of spray oils would provide equivalent pest control with less oil deposit on the foliage. This might alleviate the reduction of the percentage of total soluble solids of the juice caused by oil sprays.

Results of applications of conventional amounts of California spray oils were compared with those of lower concentrations of narrow-cut petroleum fractions of naphthenic and paraffinic composition. Insecticidal efficiency comparisons of these spray mixtures are given in the first two papers of this series (Riehl & Carman 1953; Riehl & Jeppson 1953). Observations of the amount of leaf drop and determinations of the juice quality are reported in this paper.

EXPERIMENTAL OILS.—A description of the oils used, and of the important physical characteristics of the two stock oils and of the series of fractions of each, are given in the first paper of this series (Riehl & Carman 1953).

PROCEDURE.—A full-coverage type of application was used in these experiments, and sufficient volume was applied to each tree to wet the foliage to the point of drip. The various narrow-cut petroleum fractions were applied in aqueous emulsion prepared by the tank-mixture method (Smith 1932), using 4 ounces of blood albumin spreader per 100 gallons of spray mixture. Spraying was done manually with standard orchard spray equipment utilizing a high-pressure, reciprocating-type pump operated at a pressure of 550–600 pounds per square inch. The length of the spray hose was approximately 75 feet. The diameter of the orifice of the spray gun disc was 8/64 inch. Seasonal timing of the applications and procedures with respect to the condition of the orchard were in accord with those customary for oil sprays. Applications followed irrigation. Spraying was not done when temperatures were above the maximum[3] for the district or when there was a sharp and extreme reduction in relative humidity.

The experimental design used in the Valencia orange orchard at Fullerton was that of randomized blocks, with 4 trees in a square per plot, replicated twice. The experimental block for these plots consisted of 12 rows of 12 trees each. The experimental design used in the navel orange orchard at Riverside is described in the first paper of this series (Riehl & Carman 1953), and the designs used in

[3] The Agricultural Code of California, chapter 1a, section 160.5, authorizes the county agricultural commissioners to set maximum temperatures for oil spray application in the various localities (usually between 85° and 95° F.).

the lemon orchard at Somis and in the Valencia orange orchard at Santa Paula are described in the second paper (Riehl & Jeppson 1953), in which the efficiency of various narrow-cut petroleum fractions for the control of California red scale, *Aonidiella aurantii* (Mask.), and of the citrus red mite, *Metatetranychus citri* (McG.) respectively, are reported.

Leaf Drop.—The amount of leaf drop following application of the various narrow-cut petroleum fractions was estimated in two of the experimental blocks, one in the Valencia orange orchard at Fullerton and the other in the navel orange orchard at Riverside. Leaf drop was measured by counting the number of mature leaves on the ground within a specified unit area under the tree at the end of a given interval.

At Fullerton, a box 16.5 inches long by 13.5 inches wide by 6 inches deep, commonly known as a lug box, was placed underneath each tree at the south side of the trunk and midway between the trunk and the skirt of the tree. Fourteen days after the trees had been sprayed, the mature leaves caught in the box were counted and discarded. A wind of sufficient force to blow the leaves about occurred in the area during the third week after the application, and all the leaves in the boxes at the end of the third week were discarded. Subsequently, a count was made of the number of mature leaves caught in the boxes between 21 and 28 days after spray application.

At Riverside, the decision was made to rake the ground surface clean under the south half of each tree. The trees were large, skirt foliage was somewhat open, and the lower branches from the tree trunks were well above the ground; a nontillage system was used in the orchard, and the furrows next to the trees were well under the foliage skirts. After the spray application, the surface of the ground under the south half of each tree was raked clean. Seven days later, leaf drop for each tree was determined by counting the number of mature leaves on the ground within a rectangular unit area 16.5 inches long by 13.5 inches wide (the dimensions of the lug box described above) approximately midway between the skirt and the trunk at the south side of the tree. Similar counts were made for each tree each week for 10 consecutive weeks after the spray application. After each count, the surface of the ground under the south half of each tree was again raked clean.

Fruit Sampling and Juice Analysis.—Fruit samples for determination of juice quality were taken at random around the periphery of the tree, within a zone 3 to 8 feet above the ground.

When lemons are picked commercially, it is customary to take only fruit that is larger in equatorial diameter than a specified ring size. In the packing house the lemons are segregated into several classes based on rind color. Fruit in the "silver" category is that in the class between fruit in which the rind is completely green and that in which the rind is completely yellow. For juice quality determinations, the "silver" class provides fruit in a definite stage of maturity which has easily recognized limits. For the present tests, "silver" fruits were defined as those in which both yellow and green were present in the rind in any proportions.

At Somis, the lemon samples were collected June 20, 1950, at the time of a regular orchard pick. Three oil applications (on November 12, 1948, August 9, 1949, and March 24, 1950) of the various narrow-cut fractions had preceded the collection of fruit samples. Only fruit in the "silver" class and ring-size 6 (equatorial diameter, 2.177 inches) was taken. In each of the two replicates, two samples were taken per plot, one from each of the two rows. Each sample contained 18 lemons, 3 from each of the north and south quadrants of 3 trees in line in the row.

Valencia orange samples from the orchard at Santa Paula were taken June 6, 1950, when the orchard was harvested. In each of the two replicates, two samples were taken per plot, one from each of the two rows. Oranges having a ring size of approximately 252 (equatorial diameter, 2.498 inches) were picked. Each sample contained 24 fruits, 3 from each of the north and south quadrants of 4 trees in line in the row. Two treatment applications, one on September 30, 1948, and one on August 11, 1949, had preceded collection of fruit samples.

The treatments were applied to the navel orange trees at Riverside on August 18, 1950, and the fruit samples for juice quality determinations were collected January 17, 1951, when the orchard was

harvested. A sample of 20 fruits was taken from each tree. The ring size of the oranges picked for the sample was 176 (equatorial diameter, 2.866 inches).

Samples of fruit were brought to the laboratory for processing. Juice was obtained by reaming the fruit manually on a small power-driven machine. Excess pulp was removed in four steps: (1) by the oscillating strainer of the machine, (2) by separation in the container (this occurs readily within approximately 10 minutes), (3) by straining the separated juice through approximately 40-mesh cotton curtain fabric, and (4) by centrifuging. Determinations of juice quality were made in accord with the methods of analysis used by Sinclair *et al.* (1941). Total soluble solids were determined with an Abbé refractometer. Total acidity was determined by titrating an aliquot portion of the juice with a standard solution of NaOH with phenolphthalein as an indicator. The pH values were determined with a Beckman glass-electrode pH meter.

RESULTS.—Leaf drop following the application of various narrow-cut petroleum fractions of naphthenic and paraffinic composition used at concentrations of 2, 4, and 6 quarts per 100 gallons of spray mixture, and of representative California citrus spray oils used at 7 quarts, is shown in table 1. The data in this table show the reaction of the trees to naphthenic and paraffinic oils whose boiling characteristics correspond with or are slightly above those of the upper limits of the distillation range of spray oils used for citrus in California.

Table 1.—Leaf drop of Valencia orange trees at Fullerton, California, after application of various narrow-cut petroleum fractions of naphthenic and paraffinic composition at concentrations less than those commonly used for California citrus spray oils.

Oil	Molecular Weight	Leaves Dropped per Tree[1] After Spray Application at— 2 Qts. per 100 Gal.	4 Qts. per 100 Gal.	6 Qts. per 100 Gal.	7 Qts. per 100 Gal.
California spray-blending stock (naphthenic)					
Fraction 7	336	11.6	10.8	10.6	—
Fraction 8	352	4.9	13.5	19.9	—
Residue 9	400	9.0	12.0	18.9	—
Carnation divider oil (paraffinic)					
Residue 6	394	5.9	11.3	10.3	—
Paraffin base 1	316	4.3	8.0	13.8	—
Paraffin base 2	332	—	14.7	—	—
California spray oil (naphthenic)[2]					
Light-medium	292	—	—	—	13.1
Medium	297	—	—	—	9.6
L.S.D. at 5%		3.0	6.1	5.5	—

[1] Mean number of leaves collected per tree in prescribed area first, second, and fourth weeks after spray application.
[2] California Department of Agriculture classification (Erb 1932; Marshall 1932).

Table 2.—Leaf drop of navel orange trees in a grove at Riverside, California, after application of various narrow-cut petroleum fractions of naphthenic and paraffinic composition at concentrations less than those commonly used for California spray oils.

Oil	Molecular Weight	Leaves Dropped[1] After Spray Application at— 2 Qts. per 100 Gal.	4 Qts. per 100 Gal.	7 Qts. per 100 Gal.
California spray-blending stock (naphthenic)	295	117.5	69.2	—
Fraction 1	220	—	107.5	—
Fraction 2	267	—	66.3	—
Fraction 3	279	—	58.5	—
Fraction 4	295	—	74.5	—
Fraction 5	306	71.2	72.7	—
Fraction 6	323	83.5	103.7	—
Fraction 7	336	77.2	86.2	—
Fraction 8	352	101.3	130.0	—
Carnation divider oil (paraffinic)	326	79.5	84.7	—
Fraction 1	245	—	65.0	—
Fraction 2	270	83.0	76.2	—
Fraction 3	290	76.7	80.3	—
Fraction 4	308	65.0	72.8	—
Fraction 5	329	73.2	143.3	—
Paraffin base 2	332	—	114.8	—
California spray oil[2]				
Light-medium	292	—	—	109.3
Medium	297	—	102.0	127.3
L.S.D. at 5%		60.6	43.7	—

[1] Mean number of leaves dropped per tree per week in prescribed area for 10 consecutive weeks.
[2] California Department of Agriculture classification (Erb 1932, Marshall 1932).

The effect of increase in molecular weight of naphthenic and of paraffinic petroleum compositions in the distillation range of California citrus spray oils on the amount of leaf drop of navel orange trees at Riverside following application in aqueous spray mixture is shown in table 2.

In tables 3 and 4 the effects on citrus juice quality of structural composition and molecular weight of narrow-cut naphthenic and paraffinic petroleum fractions applied in spray mixtures at relatively low concentrations are compared with those of California spray oils at the conventional concentration of 7 quarts per 100 gallons of spray mixture.

DISCUSSION.—Results listed in tables 1 and 2 show that when the concentration of the narrow-cut petroleum fractions in the spray mixture was less than 7 quarts per 100 gallons (equivalent to the 1.75 per cent used conventionally in California),

Table 3.—Comparison of juice quality of lemons sprayed with narrow-cut petroleum fractions of naphthenic and paraffinic composition[1] or with California sprays oils used at the conventional concentration.[2]

Oil	Molecular Weight	Spray Oil: 1 Qt. per 100 Gal. Soluble Solids (Per Cent)	1 Qt. per 100 Gal. Acid (Citric) (Per Cent)	2 Qts. per 100 Gal. Soluble Solids (Per Cent)	2 Qts. per 100 Gal. Acid (Citric) (Per Cent)
California spray-blending stock (naphthenic)	295	8.07	5.95	7.94	5.80
Fraction 1	220	—	—	—	—
Fraction 2	267	—	—	—	—
Fraction 3	279	—	—	—	—
Fraction 4	295	—	—	—	—
Fraction 5	306	—	—	—	—
Fraction 6	323	—	—	8.20	6.04
Fraction 7	336	—	—	7.70	5.82
Fraction 8	352	—	—	8.19	6.18
Residue 9	400	—	—	7.90	5.65
Carnation divider oil (paraffinic)	326	—	—	7.92	5.89
Fraction 1	245	—	—	—	—
Fraction 2	270	—	—	—	—
Fraction 3	290	—	—	7.86	5.83
Fraction 4	308	7.97	5.85	7.96	5.86
Fraction 5	329	7.92	6.01	8.27	6.15
Residue 6	394	8.24	6.06	8.12	5.88
Paraffin base 2	332	—	—	8.01	6.05
Paraffin base 3	334	8.15	5.95	8.23	6.05
Paraffin base 4	359	7.70	5.79	7.96	5.93
L.S.D. at 5%		0.39	0.33	0.39	0.33
		Concentration, 7 Quarts/100 Gallons			
California spray oil (naphthenic)[3]					
Light-medium	292	8.19	6.07		
Medium	297	7.99	5.85		

[1] Used in aqueous emulsions at relatively low concentrations.
[2] Values listed represent means of four samples each.
[3] California Department of Agriculture classification (Erb 1932; Marshall 1932).

increases in the molecular weight of oils of naphthenic and of paraffinic composition, within the range of 200 to 350, did not cause more leaf drop following application in aqueous spray than occurred under comparable conditions for light-medium-grade and medium-grade California spray oils. At the concentrations used, the difference between leaf drop of trees treated with naphthenic oils and of those treated with paraffinic oils was not appreciable.

The data of table 2 indicate that within each of the structural types an increase in molecular weight is likely to be associated with an increase in the amount of leaf drop. These results agree in principle with the conclusions of Smith (1932) and Ebeling (1950, p. 179). It is quite likely that the effect would have been more evident if the fractions had been used at higher spray mixture concentrations. It was one of the objectives of the experiments to determine the amount of leaf drop following the application of oils of high insecticidal efficiency, when these oils were used in the proper spray mixture concentration for adequate pest control. As pointed out above, leaf drop was not greater with such sprays than with California spray oils at the conventional dosage.

The results presented in tables 3 and 4 show that the value for the percentage of total soluble solids is significantly less for fruit of several of the narrow-cut fraction treatments than it is for comparable fruit sprayed with light-medium-grade California spray oil, although the concentration of the latter in the spray mixture was nearly twice as much. It is evident that no gain in juice quality, in the form of an increase in the percentage of total soluble solids in oranges or in the percentage of acid in lemons, occurred as a result of any of the treatments used in these experiments, in comparison with results of spraying with conventional dosages of California citrus sprays oils.

There is an indication in the results shown in tables 3 and 4 that a significant reduction in the percentage of total soluble solids of the juice occurred more times among the paraffinic fractions than among the naphthenic. Other pertinent data from subsequent experiments[4] are available and will be reported in full at a later date. These data lend support to the indications apparent in the data presented in tables 3 and 4. The deleterious influence of petroleum spray oils on citrus, as reflected by the effect on juice quality, may be greater for highly paraffinic oils than for naphthenic oils. Increasing the paraffinicity of spray oils for use on citrus should be done cautiously until further information is available on the the nature of the effect of petroleum-type hydrocarbons on the physiological function of citrus.

Among the paraffinic fractions, the effect of the oil on the percentage of total soluble solids of Valencia oranges is not consistent with the gradient in molecular weight. Examination of the physical and chemical properties of the various fractions of the series did not bring out any discrepancies in the properties which might be associated with the differences. Further information is needed on the

[4] Data on file at the University of California Citrus Experiment Station, Riverside.

Table 4.—Comparison of juice quality of oranges sprayed with narrow-cut petroleum fractions of naphthenic and paraffinic composition[1] or with California spray oils used at the conventional concentration.[2]

Oil	Valencia Oranges				Navel Oranges			
	Spray Oil 1 Qt./100 Gal.		Spray Oil 2 Qts./100 Gal.		Spray Oil 2 Qts./100 Gal.		Spray Oil 4 Qts./100 Gal.	
	Per Cent							
	Soluble Solids	Acid (Citric)	Soluble Solids	Acid (Citric)	Soluble Solids	Acid (Citric)	Soluble Solids	Acid (Citric)
California spray-blending stock (naphthenic)	10.27	1.01	10.04	1.08	—	—	11.19[3]	1.11
Fraction 1	—	—	—	—	—	—	12.26	1.16
Fraction 2	—	—	—	—	—	—	11.66	1.16
Fraction 3	—	—	—	—	—	—	11.62	1.06
Fraction 4	—	—	—	—	—	—	11.86	1.09
Fraction 5	—	—	—	—	—	—	11.99	1.10
Fraction 6	—	—	—	—	—	—	12.15	1.15
Fraction 7	9.95[3]	1.01	9.89[3]	1.04	—	—	11.55	1.16
Fraction 8	9.99[3]	1.04	10.41	1.10	11.69	1.08	11.90	1.01
Residue 9	10.09	1.07	10.13	1.02	—	—	—	—
Carnation divider oil (paraffinic)	10.25	1.03	10.06	1.02	—	—	11.08[3]	0.98
Fraction 1	—	—	—	—	—	—	12.13	1.08
Fraction 2	—	—	—	—	—	—	11.96	1.10
Fraction 3	—	—	9.86[3]	1.04	—	—	12.58	1.24[3]
Fraction 4	10.06	1.07	10.32	1.11	—	—	11.39	1.07
Fraction 5	9.99[3]	1.03	9.91[3]	0.98	11.62	1.03	12.04	1.18[3]
Residue 6	10.13	1.02	9.55[3]	1.02	—	—	—	—
Paraffin base 2	10.26	1.03	9.67[3]	0.94	—	—	10.13[3]	0.96
Paraffin base 3	10.14	1.05	10.24	1.05	—	—	—	—
Paraffin base 4	9.87[3]	1.00	10.04	1.00	—	—	—	—
California spray oil (naphthenic)[4]								
Medium	—	—	—	—	—	—	12.42	1.17[3]
L.S.D. at 5%	0.36	0.22	0.36	0.22	0.80	0.10	0.80	0.10
	Concentration, 7 Quarts/100 Gallons							
California spray oil (naphthenic)[4]								
Light-medium			10.40	1.04	12.01	1.06		
Medium			9.86[3]	0.99	11.27	1.09		

[1] Used in aqueous emulsion at relatively low concentrations.
[2] Values listed for Valencia oranges represent means of four samples each; those for navel oranges, means of six samples.
[3] Mean value for treatment differs significantly from comparable mean value for California light-medium spray oil (selected as the standard treatment for comparisons).
[4] California Department of Agriculture classification (Erb 1932; Marshall 1932).

manner in which petroleum oil applied to the foliage of a citrus tree affects the accumulation of sugars and acid in the fruit juice. Such information might make it possible to evaluate the differences in the effect on the percentage of total soluble solids indicated in table 4 for the various oils.

SUMMARY AND CONCLUSIONS.—Members of two series of special narrow-cut fractions representing distinctly naphthenic and paraffinic types of highly refined petroleum oil were applied to lemon, Valencia orange, and navel orange trees in southern California. The fractions were used in aqueous spray mixtures at concentrations of 1, 2, and 4 quarts per 100 gallons. The amount of leaf drop and determinations of the quality of the juice of fruit harvested subsequent to the application are reported for the various narrow-cut fractions and for a proprietary California citrus spray oil used at the rate of 7 quarts per 100 gallons (1.75 per cent) of spray mixture.

From the foregoing experiments, the following conclusions were drawn: (1) No gain in juice quality in the form of an increase in the percentage of total soluble solids of oranges or in the percentage of acid of lemons occurred from treatments with the low concentrations of the narrow-

cut fractions. (2) There was evidently no relationship between the molecular weight gradient of petroleum fractions in the range 200 to 350 and the effect of the oil on the percentage of total soluble solids and on the percentage of acid of citrus juice. (3) The difference in leaf drop from trees treated with naphthenic oils and from those treated with paraffinic oils was not appreciable. (4) It is indicated that although an increase in leaf drop following application of oil sprays may accompany an increase in the molecular weight of petroleum fractions in the range 200 to 350, the leaf drop was not greater from trees sprayed with the narrow-cut fractions than from those sprayed with California citrus spray oils of light-medium and medium grades.

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Fecundity of the Pea Aphid on Garden Pea Under Various Combinations of Light, Moisture, and Nutrients[1,2]

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Previous notes by the writers have indicated that whereas the developmental period of *Myzus persicae* (Sulz.) was not significantly affected by changes in its host plant (1951a), the longevity of another aphid, *Macrosiphum pisi* (Kltb.), was decreased by a reduction in the level of nutrient fertilization (1951b). The primary cause in decreasing the longevity of *M. pisi* was increased aphid injury on nutrient deficient plants, thus making the host less suitable for optimum aphid survival. Arising from these investigations was a further study into the effect of changes in the host upon the fecundity of *M. pisi*.

MATERIALS.—Data regarding changes in fecundity of *Macrosiphum pisi*, as influenced by nutrition of its host, was obtained from aphids reared on garden peas, *Pisum sativum* L., growing in a 3:1 sand-soil mixture. Clarion type soil with a low organic matter content was screened, air dried, and then mixed with white quartz sand. Eight-inch pots were filled with the mixture, covered with cheesecloth and sterilized at 15 pounds pressure for 3 hours. Seeds were sterilized with 10 per cent hydrogen peroxide solution for 15 minutes to remove nitrogen fixing bacteria

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[2] The writers express their appreciation to Dr. W. E. Loomis, Iowa State College, for suggestions concerning manipulation of plant growth factors, and to Mr. Paul G. Homeyer, Iowa State College, for his aid in statistical treatment of data.

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Table 1.—Analysis of variance and mean values of total number of progeny[1] produced by *Macrosiphum pisi* reared on *Pisum sativum* previously grown for varying lengths of time on different light and moisture levels and various nitrogen levels.

		High Light, Low Moisture	Low Light, High Moisture	
		Age at Infestation		Age at Infestation
		Mean Squares		
Source of Variation	Degrees Freedom	4 Weeks	6 Weeks	5 Weeks
Total	11			
Replicates	3	18	22	6
Nitrogen levels	2	25	66	9
Error	6	23	18	10
	Nitrogen Levels (Lbs. per Acre)	*Actual Means* 4 Weeks	6 Weeks	5 Weeks
	0	48	48	44
	50	48	51	41
	200	44	43	42
	Average	46.8	47.4	42.3

[1] Average of two females per replicate.

Experiments with the sand-soil medium were designed to test the following points: (a) Changes in fecundity as influenced by levels of nitrogen available to the plant; (b) The same changes as influenced by a high or low carbohydrate level in the host plant.

Experimental plants for the first part of the design [(a), above] were obtained with different levels of nitrogen application, namely, 0, 50 and 200 pounds of actual nitrogen per acre. The source of nitrogen was ammonium nitrate. Plants were also supplied with potassium sulfate and potassium phosphate at the rate of 500 pounds per acre. To secure plants for the second part of the design [(b), above], it was necessary to superimpose on the first design different light and moisture levels. In so doing it was necessary to determine the moisture content of the sand-soil mixture. Pots which had been equalized in weight were filled with a uniform amount of the mixture. Then the moisture content at field percentage was determined, and, by utilizing this figure, two moisture levels were maintained throughout the experiment.

A high moisture level was obtained by watering pots to 150 per cent of field percentage each day, as they came back to field percentage. Plants grown under this condition were also subjected to a light level approximately 25 per cent of normal by shading with bleached muslin. This high moisture treatment in combination with low light produced plants low in carbohydrates. A lower moisture level was obtained by watering the pots to 115 per cent of field percentage approximately 1 day after they came back to field percentage. These plants were grown under normal light, and consequently, were high in carbohydrates.

Four replicates per nitrogen level, per light and moisture combination, were used, with each replicate consisting of one pot containing four plants. Also, plants on high light and low moisture were tested at different ages, namely, 4 and 6 weeks. This was done in order to test different degrees of nitrogen deficiency. However, plants under low light and high moisture treatment were very susceptible to root rotting fungi, and were tested at 4 to 5 weeks of age only. Since the difference of 1 week seemed to cause little change in these plants, the results so obtained are compared on an equal basis with the 4- and 6-weeks testings on the high light and low moisture treatment. Therefore, the entire experiment consisted of 36 pots containing four plants each; 24 of these being grown under high light and low moisture and the remaining 12 under low light and high moisture.

Aphid Rearing Methods.—First instar females for infestation were obtained by placing gravid females on young pea plants for 3 to 4 hours, during which they produced offspring freely. As soon as test plants were infested, they were surrounded with cylinders made from cellulose acetate sheeting. Cheesecloth-covered top and windows, cut in the side of the cages, afforded ventilation. At the time of removal of the cages to make counts, particular caution was taken not to disturb the plant, because agitation caused the aphids to drop from the plant, making an accurate census virtually impossible. These data are shown in table 1.

The collection of data relative to the effect of the nitrogen, light, and moisture levels was done in a manner similar to that described (1951b). First instar aphids were also used for infestation. However, the method of making fecundity counts

was modified in order to save the young as material for total nitrogen and lipid analyses which will be reported in a later paper. Instead of removing the young every 3 days as previously mentioned (1951b), only one removal and count were made at the end of 6 days after maturity of the parent females. Also, the sample size was reduced to two females per plants, and four plants per pot were infested. The fecundity figures expressed in tables 1, 2, and 3 are the average number of young produced per female on each treatment.

The sample size was reduced to two females in these experiments to prevent over-crowding and plant injury effects. Even with this reduction, some plant injury symptoms appeared on the low light and high moisture treatment, but were not considered sufficient to warrant further modification of the method.

After removal from the plant, the young aphids were first chilled in a refrigerator set at 40° F., and then counted.

RESULTS AND DISCUSSION.—It is necessary to refer to a report by the writers (Barker and Tauber 1951b) in order to interpret reductions in fecundity on nutrient deficient plants. Experimental results were presented to show that nutrient deficient *Pisum sativum* plants were injured worse by *Marcrosiphum pisi* than

Table 2.—Analysis of variance of total number of progeny[1] produced by *Macrosiphum pisi* reared on *Pisum sativum* previously grown for varying lengths of time on different light and moisture levels and various nitrogen levels; data analyzed for effect of light and moisture levels.

Source of Variation	Degree of Freedom	Low Light, High Moisture at 5 Weeks vs. High Light, Low Moisture at 4 Weeks	6 Weeks
		Mean Squares	
Total	23		
Light and moisture levels	1	126.1[2]	160.1[2]
Replications within light and moisture levels	6	11.6	13.7
Nitrogen levels	2	23.1	40.1
Nitrogen levels×light and moisture levels	2	10.3	35.3
Error (pooled)	12	16.3	13.9

[1] Average of two females per replicate.
[2] Significant at P≦0.01.

Table 3.—Analysis of variance of total number of progeny[1] produced by *Macrosiphum pisi* reared on *Pisum sativum* previously grown for varying lengths of time on high light and low moisture and various nitrogen levels.

Source of Variation	Degree of Freedom	Mean Squares
Total	11	
Replicates	3	8.26
Nitrogen levels	2	82.18[2]
Error (a)	6	6.33
Total	23	
Time	1	2.05
Time×nitrogen levels	2	7.94
Error (b)	9	35.06

[1] Average of two females per replicate.
[2] Significant at P≦0.01.

were full nutrient plants. The difference in degree of injury was sufficient to cause a significant reduction in length of life of the deficient plants and, consequently, a reduction in longevity of *M. pisi*. This increased injury of nutrient deficient *P. sativum*, and its resultant decrease in longevity of *M. pisi*, are interpreted as being largely responsible for the reduction in fecundity of the aphid. It is possible that there may have been a direct nutritional effect upon *M. pisi*, but the writers believe this to be of secondary importance under the conditions of the above experiments.

Examination of data in table 1 suggests a decreasing level of fecundity as the level of nitrogen fertilization increased on the high light, low moisture plants. This, of course, was not displayed on the low light, high moisture plants because nitrogen was not the limiting factor with these plants. The latter were on such a reduced level of light that even the lowest level of nitrogen was adequate for their growth.

Data in table 1 also suggest a decreased level of fecundity on the low light, high moisture plants. This prompted the analysis of variance given in table 2. The effect of light and moisture level is quite obvious. The differences are highly significant regardless of the age of plants compared (between light to moisture levels). It is evident, therefore, that the fecundity of *Macrosiphum pisi* was significantly reduced when reared on plants grown under reduced light and high moisture. Interpreted in terms of actual plant conditions, highly succulent plants, such as those grown under reduced light and high moisture were not as conducive to the production of young by *M. pisi* as were

well differentiated plants grown under normal light and ample, though comparatively less, moisture. This interpretation, though well supported by these data, is contrary to general belief that highly succulent plants favor maximum reproduction in aphids. This supposition is probably based on the observation of increased injury usually noted on succulent plants. This could imply a greater reproduction. Actually, as was observed in these tests, the reduced number of young produced on the highly succulent plants caused more injury to these plants than did the higher number of young produced on the well differentiated plants. Apparently, well differentiated plants, such as are produced under normal growth conditions, are more tolerant of aphid injury than are highly succulent plants.

The indication of an increased level of fecundity on low nitrogen plants under high light and reduced moisture prompted the analysis presented in table 3. Data from the 4- and 6-weeks plants are combined and analyzed for age effect (time) which in the same analysis reveals a significant effect of nitrogen levels not otherwise shown. Regardless of the statistical combination, it is plain to see from these tests, that as the level of nitrogen increased on these high light, low moisture plants, the fecundity of *Macrosiphum pisi* decreased. In addition to the increased fecundity on these low nitrogen plants, these plants were less tolerant of aphid injury than were the high nitrogen plants. It appears, therefore, that as the level of nitrogen fertilization increased, on these full-light, reduced moisture plants, tolerance of *M. pisi* injury increased. However, the fecundity of *M. pisi* decreased as the level of nitrogen increased.

Based upon the above data, a suggestion is offered to account, at least partially for tolerance of aphid injury by a *Macrosiphum pisi* host-plant. It would appear, from these tests, to be a function of growth and differentiation. When growth is proceeding in the presence of little or no differentiatton, injury is worse, even to the point of complete destruction. On the other hand, when both growth and differentiation are limited because of the lack of nitrogen, *M. pisi* injury could be expected. Another point suggested by these data is that degree of injury is not necessarily a population index. It might be reliable where growth factors were uniform among comparisons, but would be an extremely poor index if factors such as level of fertilization, light, and moisture were purposefully or otherwise changed. From the practical viewpoint, it seems reasonable to conclude that a well balanced fertilizer program in terms of soil conditions would offer considerable, though certainly not complete, protection against *M. pisi* injury. Succulence, such as was obtained under reduced light and high moisture, should be avoided not so much because of greater aphid reproduction but because of injury sustained by such plants.

CONCLUSIONS.—Highly succulent plants, such as produced under conditions of reduced light and high moisture, were not as conducive to production of young aphids as were well differentiated plants.

Fecundity of *Macrosiphum pisi* decreased as the level of nitrogen fertilization increased with pea plants cultured under conditions of full light and lower moisture. Also, plant injury decreased as nitrogen levels increased; thus a plant on high nitrogen was more tolerant of pea aphid feeding.

Inasmuch as previous investigations have shown that nutrient deficient pea plants are more severely injured by pea aphids, and that the longevity of *Macrosiphum pisi* on deficient plants is reduced, it is concluded that the decreased fecundity results from a combination of the above two influences rather than from a direct physiological effect upon the reproductive mechanism.

Degree of injury to plants by aphid feeding is not necessarily an index to aphid population unless growth factors between or among comparisons are uniform.

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The Influence of the Sweetclover Weevil and Soil Fertility on Sweetclover Stands[1]

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Studies on the sweetclover weevil, *Sitona cylindricollis* Fabr., and its control have been carried on in Indiana for six seasons. In 1951, Wilson reported studies on the use of insecticides to control this pest. He also found increased vigor could be obtained by combining DDT with a top dressing of superphosphate. This treatment enabled the plants to grow faster and overcome much of the weevil injury. Since that time, studies have been continued in cooperation with the Agronomy Department to determine the importance of combined weevil control and high fertility in obtaining sweetclover stands.

Effect of Soil Fertility Level on the Early Growth of Sweetclover.—Albrecht, *et al.*, (1948), and Davis & Turk (1943), found the rate and magnitude of sweetclover growth to be influenced by fertilizer applications. The amount of influence is affected by the starting fertility level of the soil.

Methods.—A study to determine the soil fertility level required to give maximum growth to sweetclover was made in the greenhouse during early spring in 1951. According to the analysis of the Purdue University Soil Testing Laboratory, the soil used was a Raub silt loam, having a phosphate level of 60 pounds per acre, potash level of 100 pounds per acre and pH of 5.3. It was limed at the rate of 6 tons per acre. The fertilizer treatments were thoroughly mixed with the soil on January 30. The sweetclover was planted February 21 and harvested March 23. Three replicates of each treatment were used. The fertilizer treatments applied and their influence on the level of fertility in the soil and on sweetclover growth are shown in Table 1.

Results.—The effect of phosphate on sweetclover growth was most striking. The yield of sweetclover increased with increasing phosphate application up to the highest application rate of 1600 pounds per acre. Potash applications of over 100 pounds per acre did not give increases. More than 400 pounds caused a decrease. Nitrogen or extra lime did not increase growth.

Effect of Combining Fertilizer Application with Weevil Treatment. Experiments I and II.—In the season of 1951 DDT was combined with fertilizers and applied to sweetclover in two experiments; one in which the sweetclover was

[1] Journal paper, No. 753.
[2] Co-leaders of sweetclover project, Departments of Entomology and Agronomy respectively.

Table 1.—Greenhouse studies showing the effect of different levels of soil fertility on sweetclover.

Fertilizer Application		Soil Test[1]			Yield of Sweetclover—Grams per Three Pots
P_2O_5	K_2O	P_2P_5	K_2O	pH	
0	400	53	330	6.7	21.0
100	400	100	260	6.7	37.0
200	400	150	250	6.6	38.0
400	400	300	250	6.9	40.5
800	400	660	250	6.6	44.0
1600	400	1400	230	6.4	50.0
800	1600	660	1450	6.4	29.0
400	800	310	760	6.6	36.0
400	200	310	160	6.6	45.5
400	100	290	120	6.7	46.0
400	0	280	100	6.9	38.5
400	800 (+200N)	310	830	6.4	31.5
400	800 (+2 tons lime)	310	780	7.0	37.5
L.S.D. (5%)					11.7

[1] Tests made by Purdue University Soil Testing Laboratory using an extracting solution of 15 ml. of 0.75 N HCl to 5 grams of soil and shaken for 2 minutes.

Table 2.—Experiments I and II.—A comparison of weevil injury, plant vigor, and clover stand in wheat and oats one month following treatment with sweetclover stand in wheat in November.

Pounds of Active Ingredients per Acre				Visual Ratings[1]			
				May 1951			Nov. 1951
DDT	Nitrogen	P_2O_5	K_2O	Weevil Injury	Plant Vigor	Clover Stand	Clover Stand
				6.5	7.8	5.8	4.3
	40			4.0	3.9	3.5	5.0
1	40			4.3	4.8	3.4	5.4
2	40			3.8	4.2	3.3	6.8
	40	60		5.4	4.4	4.0	7.6
1	40	60		3.6	4.2	4.3	3.9
2	40	60		4.0	3.7	3.6	4.8
	40	60	80	3.7	2.9	2.4	7.0
1	40	60	80	3.5	3.5	3.5	5.6
2	40	60	80	4.5	3.1	2.9	5.8
		60		6.3	6.4	7.2	2.5
1		60		7.1	6.8	5.9	4.3
2		60		6.3	7.1	5.9	2.2
1				7.2	7.1	5.9	2.9
2				6.3	6.9	5.9	2.4
L.S.D.		5%		1.9	1.7	0.7	3.3
		1%		2.6	2.3	0.9	4.4

[1] Visual ratings using scale of 1–9; 1–3 very good, 4–6 average, 7–9 poor.

sown in wheat, the other in oats. Materials were applied in the early spring at the time of sweetclover emergence. These experiments were combined for analysis and data are shown in Table 2.

Methods.—A replicated block design was used with plots measuring 30×30 feet. Using a Gandy fertilizer spreader, an area 20×20 feet was treated in each plot, leaving a border 5 feet wide.

Results.—The most significant differences were due to fertilizer effects. Analysis of the soil showed a favorable pH and a high amount of phosphate, but a deficiency in potash. At Washington, Indiana in the experiment in wheat, immediate response to both nitrogen and potash occurred. The first month sweetclover grew vigorously and was able to withstand weevil infestation in all plots treated with nitrogen.

However, within a few weeks the picture was reversed: the nitrogen likewise greatly stimulated the companion cereal crop and probably as a result of shading and competition by the wheat, the sweetclover practically disappeared from all treatments which had been top-dressed with nitrogen. Ratings of the sweetclover stand in the wheat in the fall showed a greatly decreased stand after the month of May on plots treated with nitrogen, but a gradual increase on plots receiving no nitrogen or just superphosphate. Unfortunately, there was not a treatment of potash without nitrogen so it is not known what the full impetus of potash might have been. Although the desired abundance of stand was not obtained, the data clearly show the importance of fertility in obtaining sweetclover stands.

Without doubt, in many cases top dressing wheat with excessive amounts of nitrogen has contributed greatly to the reduction of sweetclover stands. It produces vigorous wheat which is highly competitive for nutrients and, through shade, for sunlight. This latter factor is also important from the fact that shading of the clover creates a more suitable habitat for the weevils. The sweetclover weevil is most active in a cool environment. Hot June days quickly lower the population of weevils, particularly if their habitat is exposed to the bright sun

EXPERIMENT III.—During the seasons of 1952 and 1953 a study was conducted to determine not only the effect of increased soil fertility and weevil control on vigor and the maintenance of sweetclover stands, but also on the root weight and nitrogen in the roots.

Methods.—For this study only four treatments were used; untreated, DDT

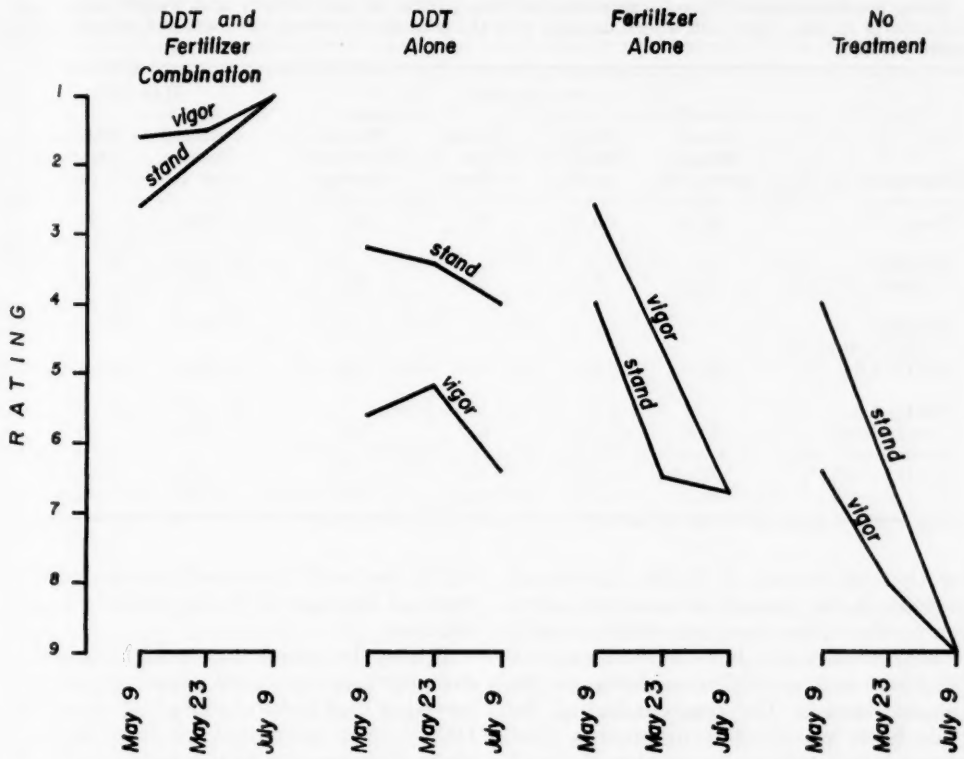

FIG. 1.—The effect of weevil control and high soil fertility on sweetclover vigor and stand.

alone, fertilizer alone, and DDT and fertilizer in combination. A heavy phosphate—potash formulation of 1100 pounds of 0–15–15 was used per acre in fertilizer treatments, while 2 pounds of DDT per acre were used on plots where weevil control was desired. Treatments were applied at the time of emergence with a Gandy spreader to six replicates. Plots measured 40×40 feet.

The following data were taken: 3 weeks and 5 weeks after treatment estimates of stand, plant vigor, and weevil injury were made using a scale rating of 1–9 (1, very good; 9, poor; and 5, average). Seven weeks after treatment plants were selected at random from each plot and the average height per plant, the average number of leaves per plant, and the leaf surface chewed by weevils were measured. From the latter the per cent leaf surface chewed was calculated. Twelve weeks after treatment, following wheat harvest and the removal of the straw, a stand count was made in each plot. This count was obtained by averaging 12 square-foot samples from each plot. The following spring, the roots from 3 square-yard samples in each plot were dug. The average dry weight was determined and the per cent nitrogen calculated following laboratory analysis.

Results.—Figure 1 shows the effect of weevil control and high fertility on sweetclover vigor and stand as observed on three dates; May 9, May 23, and July 9. Figure 2 shows the pounds of nitrogen produced per acre by each treatment. Table 3 compares the final stand count, clover vigor, leaves per plant, and weevil damage in July following wheat harvest with the pounds of roots and pounds of nitrogen produced per acre the following April.

These data show in all cases increased stand, greater vigor, more leaves per plant, less weevil damage and more roots per acre, resulting in more nitrogen per acre from the crop where a combination treatment of DDT and fertilizer was used.

These data show that weevil control and soil fertility were equally important

Table 3.—Experiment III.—A comparison of the effects of soil fertility and weevil control on sweetclover stands, vigor, and weevil damage with the pounds of sweetclover roots and nitrogen produced per acre.

Treatment per Acre	July 9, 1952				May 1953	
	Stand Plants per Sq. Ft.	Vigor Height in In.	Leaves per Plant	Weevil Per Cent Damage	Roots Pounds per A.	Nitrogen Pounds per A.
None	6.0	5.5	6.1	31	1135	41.1
Fertilizer 1100 lb. 0-15-15	8.0	6.4	6.7	42	1597	58.5
Fertilizer 1100 lb. 0-15-15 DDT—2 lb.	12.0	8.4	8.9	19	2101	77.6
DDT—2 lb. no fertilizer	10.0	6.5	6.7	16	1513	55.7
L.S.D. 5%	3.2	1.0	1.5	7	274	12.3
1%	4.5	1.4	n.s.	10	378	17.0

for the experiment. A highly significant increase in the pounds of roots and nitrogen produced per acre was obtained with either increased fertility or weevil control, but there was no difference between the two treatments. The combination of the two, however, showed differences that were again significantly greater at the 1 per cent level than either treatment by itself. The data indicate that there was an interaction between the fertilizer and DDT, but with the small number of degrees of freedom it lacks statistical significance.

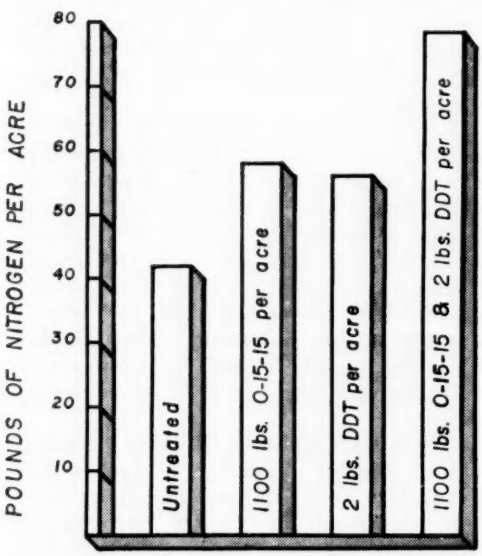

FIG. 2.—The effect of weevil control and high soil fertility on the total nitrogen produced per acre in sweetclover roots.

It may be noted that a highly significant increase in weevil chewing was observed in high fertility plots (not receiving DDT) over untreated or low fertility plots. This was due to the greater vigor of plants in the high fertility plots. These plants without the protection of DDT survived even though badly chewed and produced a stand averaging two more plants per square foot than the untreated low fertility plots. The lower estimate of weevil chewing on the untreated plots does not take into consideration the large number of plants killed and, therefore, not sampled.

EXPERIMENT IV.—Because of the increasing practice of spraying cereals with liquid nitrogen and the difficulty of combining DDT with a powdered fertilizer, studies were conducted in 1953 to determine the possibility of combining DDT with liquid nitrogen and applying the mixture in a spray. Since it is desirable to apply nitrogen early, the study was planned to determine a date when the combination could be applied to effectively increase wheat yields and also control the sweetclover weevil.

Methods.—A large scale Latin square design was used with five treatments; untreated, nitrogen applied alone on April 11, nitrogen applies with DDT on April 30, and DDT applied alone on May 19.

Table 4.—Experiment IV.—The use of DDT for sweetclover weevil control in combination with liquid nitrogen.

Treatment per Acre	Date of Application	Visual Ratings[1]						Wheat Yield, Bu. per Acre
		Stand		Vigor		Weevil Damage		
		May 29	July 3	May 29	July 3	May 29	July 3	
None		7.1	8.8	8.1	8.0	8.8	8.6	31
Nitrogen 22 lbs. DDT—two lbs.	April 11	2.6	3.2	3.1	3.4	1.4	2.8	41
Nitrogen 22 lbs. DDT—two lbs.	April 30	2.1	3.2	2.3	3.6	2.4	2.6	41
Nitrogen 22 lbs.	April 11	2.6	6.2	4.4	8.0	7.2	6.6	39
DDT—two lbs.	May 19	4.1	4.6	6.2	4.0	8.2	3.6	29
L.S.D. 5%		1.6	2.3	1.8	2.4	1.4	2.3	
1%		2.3	3.2	2.6	3.4	2.0	3.2	

[1] Ratings using scale of 1–9; 1–3 good stand, high vigor, high weevil control; 4–6 average ratings; 7–9 poor stand, low vigor, heavy weevil damage.

Nitrogen was applied at the rate of 22 pounds per acre and DDT at the rate of 2 pounds. Plots were a little over one-fourth acre, being 60×200 feet. Treatments were applied with a tractor mounted sprayer designed for the application of liquid nitrogen. Twenty-five per cent DDT emulsion was added to the liquid nitrogen (an ammonium nitrate and urea mixture) and mixed in the tank.

Results.—Table 4 compares the ratings for sweetclover stand, vigor, and weevil damage on May 29 and July 3. Wheat yields obtained from combined strips are also included. These data show that nitrogen stimulated sweetclover growth as in Experiments I and II, but in this case was not applied in excessive amounts and the clover was not depleted by the competition of the wheat. DDT controlled the weevil, but best stands were obtained with the combinations of DDT and liquid nitrogen applied in April. There were no differences between April 11 and April 30 treatments, neither in clover stand, weevil damage, nor wheat yield. Because of the high residual effect of DDT, the treatment can probably be applied as early as April 1—upon, or just prior to, clover emergence. Therefore, timing the insecticide should not interfere with the nitrogen timing. This treatment when it can be employed is the easiest and least expensive weevil treatment devised to date. However, for vigorous stands the phosphate and potash levels of the soil must also be maintained at adequate levels.

SUMMARY AND CONCLUSIONS.—Studies during four seasons indicate that soil fertility as well as sweetclover weevil control are equally important factors in obtaining vigorous sweetclover stands. Because of the sweetclover weevil, high soil fertility is of increasing importance. High soil fertility produces vigorous plants which can better sustain the injury of the weevil. The necessity of applying fertilizer and the ratio to apply can be determined by soil tests. To protect the plants until they become established, DDT at the rate of 1.5 to 2 pounds per acre was used in combination with fertilizer and applied to the surface of the soil at the time of clover emergence.

DDT may be combined with a powdered fertilizer and applied as a top dressing to the soil or it may be combined with liquid nitrogen (an ammonium nitrate and urea mixture) and sprayed on the soil. However, data suggest that care should be taken to avoid an excessive application of nitrogen. A moderate application of nitrogen stimulated clover growth without adverse effects, while larger nitrogen applications reduced the clover stand due to competition with the companion wheat crop for nutrients and sunlight. Because of the low cost for application and the ease of combining DDT with liquid nitrogen in the regular fertili-

zer program, this method of controlling the sweetclover weevil shows greater promise than methods of applying DDT recommended heretofore. However, this does not preclude the importance of also applying a top-dressing of phosphate or a more complete fertilizer formulation when needed to produce an abundance of vigorous plants capable of withstanding heavy weevil infestation when the residual effect of the DDT is depleted.

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Beet Leafhopper Control Experiments on Snap Beans Grown for Seed[1]

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The beet leafhopper, *Circulifer tenellus* (Bak.), is the only known carrier of the curly top virus, a destructive disease affecting beans, sugar beets, and many other crops. This disease was first reported on beans by Carsner (1925) and Merrill (1925). Carsner (1926) described the symptoms of the disease on beans and expressed the opinion that serious damage to the bean crop may be expected only in seasons when beet leafhoppers are abundant. The serious losses caused by this disease were discussed by Harter and Zaumeyer (1944) and by Larson and Hallock (1942). Hallock (1946) indicated that the commercially important varieties of snap beans (those eaten green) showed significantly more curly top than susceptible Great Northern varieties of field beans (dry edible). Although the beet leafhopper does not reproduce on beans, in migrating from its weed-host breeding areas in the spring to favored cultivated hosts such as sugar beets, the insect enters bean fields and in feeding on the young plants transmits the virus to them.

Since the bean growers in southern Idaho produce approximately 80 per cent of this country's requirements of snap bean seed (Douglass & Cook 1952), the prevalence of curly top disease in this crop presents a very important problem. In view of this situation a project was started at Twin Falls, Idaho, in 1946, to develop a direct control of the beet leafhopper on snap beans grown for seed, by the application of insecticides, as a means of decreasing the incidence of curly top disease on that crop. The early research consisted principally of laboratory tests with a wide range of insecticides. The most promising of these insecticides were used in field-plot experiments conducted during the period 1948–52. The results of these experiments are given herein.

The 1948 experiments were made in cooperation with the Corneli Seed Company on its experimental grounds southeast of Twin Falls, and most of the later experiments in cooperation with the Associated Seed Growers, Inc., on its farm northwest of Twin Falls. The latter location was considered the more advantageous, since curly top exposure is more severe along the Snake River Canyon. In 1950–52 some of the experiments were conducted on rented ground west of Twin Falls.

METHODS.—Most of the experiments were conducted on small plots of Bountiful beans, which are very susceptible to curly top. The beans were planted at weekly intervals so that the emergence

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[2] This work was conducted under the supervision of J. R. Douglass. Thanks are also due to W. C. Hemingway, plant breeder for the Associated Seed Growers, Inc., and D. M. Murphy, manager of the Twin Falls, Idaho, station of the Corneli Seed Company, for their cooperation.

of the plants in one of the plantings would coincide with the peak of the spring movement of beet leafhoppers into the cultivated area. The dates of the first plantings ranged from May 24 to June 1. In 1949–51 beans were also planted in early July to secure additional data on control during late migrations. Since many growers believe that there is a greater need of protection from beet leafhoppers when the stand of beans is sparse, in two experiments the stands were thinned to 1½, 3, and 6 plants per foot.

In 1948–50 each plot was 4 rows wide and 20 feet long; in 1951 the length was increased to 40 feet. The number of treatments in each experiment ranged from 3 to 7, and they were arranged in 5 to 24 randomized blocks. The plots were marked when the plants began to emerge from the ground, and the first application of insecticides was made when they were in the "crookneck" stage of growth. Two subsequent applications were made at weekly intervals.

The sprays were applied with a 4-gallon compressed-air sprayer, one row being covered at a time, at the rate of approximately 100 gallons per acre. The dusts were applied to one row at a time with a rotary-type duster, at rates ranging from approximately 20 to 30 pounds per acre.

In two large-plot experiments the insecticides were applied at 20 to 30 pounds per acre with an 8-row power duster equipped with one nozzle per row and a 30-foot canvas hood. The plots were 16 rows wide and the length of the field. There were from 4 to 7 replications in each experiment, depending upon the size of the field. The varieties grown in these plots were Asgrow Stringless Greenpod, Dwarf Horticulture, Fulgreen, Rival, Top Crop, Top Notch Golden Wax, and Wade.

The effectiveness of the insecticides was determined by comparing the abundance of curly top-infected plants and the yield of beans in the treated and untreated plots. Population counts were not made, since leafhoppers do not reproduce on beans or remain in bean fields. The percentage of infected plants was determined by examining 100 plants from the two center rows of each plot. Yield records were taken from the same two rows. The curly top records were taken in late July and the yield records in September when the beans were harvested.

INSECTICIDES TESTED.—The insecticides tested were CS-674A, CS-708, DDT, methoxychlor, Q-137, and schradan. DDT was used as an emulsion and as a dust; CS-674A as a suspension spray; schradan as an emulsion spray; and CS-708, methoxychlor, and Q-137 as dusts. Two grades of DDT were used, the technical grade and the purified grade consisting chiefly of *p,p'*-DDT. The solvents were benzene, corn oil, an aromatic solvent, sulfonated olive oil, toluene, and a proprietary nonvolatile solvent containing chiefly di- and tri-methylnaphthalenes. All emulsions were made with a proprietary emulsifier containing 80 per cent of polyalkylaryl polyether alcohol and 20 per cent of isopropanol.

The concentrations of all sprays were made so as to apply 1½ pounds of toxicant per acre, except schradan where 1 pint of 66-per cent material was used. The dusts were generally used at 5- or 10-per cent concentrations and applied at 1 to 3 pounds of toxicant per acre. A dust containing 2.5 per cent each of DDT (technical) and Q-137 was used in four experiments in 1951 and 1952.

RESULTS.—The variations in yield of beans due to factors other than curly top and the abundance of beet leafhopper vectors are important factors to be considered when the results of these experiments are evaluated. The average yield of beans in the check plots ranged from 260 pounds per acre in 1948 to 1,769 pounds in 1951. The average number of leafhoppers entering the cultivated area ranged from 2 per square foot in 1948 and 1952 to 10 in 1950. Since 56 and 63 per cent of the spring-generation leafhoppers entering beet fields were viruliferous in 1950 and 1951, as compared with a 15-year average of 36 per cent, more curly top could be expected in the bean fields in these years. According to surveys of snap bean fields in southcentral Idaho, 5, 12, 10, 4, and 1 per cent of the bean plants in the years 1948 through 1952 showed evidence of curly top. Only in 1949 and 1950 was the percentage high enough for one to expect significant differences between treatments.

Laboratory and field studies during the last 7 years have shown that beans are susceptible to injury from insecticides. DDT caused injury to beans in some of

the tests conducted at Twin Falls by K. E. Gibson in 1947. In 1947 and 1948 DDT emulsion sprays containing di- and trimethylnaphthalenes often caused stunted beans, and plant injury ranged from none to severe.

In 1948 and 1949 curly top was reduced and the yields were increased by all the treatments. DDT emulsions prepared with corn oil or aromatic solvent caused less plant injury than those prepared with benzene, sulfonated olive oil, or toluene. The use of corn oil was discontinued in 1951 because it was too expensive.

In laboratory tests snap bean plants sprayed with an emulsion of technical DDT were significantly smaller than those sprayed with an emulsion of purified DDT containing the same solvent. In dusts purified DDT caused slightly less stunting than technical DDT under laboratory conditions. DDT dusts did not cause noticeable injury to beans in the field plots.

In 1952 from 0.5 to 1.2 per cent of the plants in the untreated plots were infected with curly top, which was comparable with results recorded in the field survey of snap beans. The percentages were too low to show any measurable differences between treatments. There is no evidence that any of the insecticides reduced yields during a year when curly top infection was not a factor.

As the exposure to viruliferous leafhoppers in 1948 was mild, curly top reduction was not significant, and increases in yields over the checks were significant in only one experiment. Since the exposure was more severe in the 1949–51 period, the average reductions in curly top and increases in yields for the plots receiving the insecticides were significant.

DDT gave the best control of the beet leafhopper, and since it was included in all experiments, each of the other five insecticides was compared with it.

The field plots that received a suspension spray of CS-674A showed a 26-per cent reduction in curly top in Bountiful beans as compared with 40 per cent for an emulsion of purified DDT.

Laboratory tests indicated that CS-708 would control the beet leafhopper without injuring the bean plants. The exploratory field test in 1950 showed a 45-per cent reduction of curly top on Bountiful beans for a 5-per cent CS-708 dust, and 35 per cent in plots receiving 5-per cent purified-DDT dust. In three experiments in 1951 the average yields for 20 replicates were 1,499 and 1,485 pounds of beans per acre for the plots receiving 5-per cent dusts of CS-708 and purified DDT, respectively, as compared with 1,298 pounds for the check plots. The dusted plots showed a 68-per cent reduction where purified DDT was applied as compared with 57 per cent when CS-708 was used which was a significant difference.

In 1950 a 5 per cent methoxychlor dust reduced curly top in beans 24 per cent, as compared with 35 per cent reduction from 5-per cent purified DDT. The 1951 experiment with 10 per cent dusts showed curly top reduction on beans of 46 and 48 per cent for the plots dusted with methoxychlor and purified DDT, respectively. The respective yields were 1,927 and 2,039 pounds of beans per acre, as compared with 1,769 pounds in the check plots.

The yield records in 1951 showed 2,293 pounds of beans per acre for plots receiving a dust containing 2.5 per cent each of Q-137 and technical DDT, 2,039 pounds for plots receiving a 10 per cent purified DDT dust, and 1,769 pounds for the check plots. Reduction of curly top did not appear to be the only factor responsible for increased yields in the plots receiving Q-137 plus DDT, as the average reduction in these plots was 44 per cent, whereas it was 48 per cent in the plots dusted with purified DDT. Since the yields in 1951 were not consistent with curly top incidence and the exposure in 1952 was too mild to materially affect yield, further tests are necessary to evaluate Q-137 for reducing curly top by controlling the beet leafhopper.

The average curly top reduction in Bountiful beans for the 24 replicated plots receiving the schradan emulsion spray was 22 per cent, as compared with 40 per cent for an emulsion spray containing purified DDT. Although this spray caused high leafhopper mortality in laboratory tests, it gave less curly top reduction than DDT emulsions under both laboratory and field conditions. In evaluating the results obtained with DDT, the data from the various experiments were combined wherever they were comparable.

The results from two experiments on Bountiful beans, summarized in table 1,

Table 1.—**Effectiveness of a 5-per cent purified-DDT dust applied to three stand densities of Bountiful beans in reducing curly top and increasing yields, 1950 and 1951.**

Treatment	Sparse Stand		Medium Stand		Dense Stand	
	Curly Top	Yield per Acre	Curly Top	Yield per Acre	Curly Top	Yield per Acre
	Per cent	*Pounds*	*Per cent*	*Pounds*	*Per cent*	*Pounds*
DDT	6.5	1,194	3.9	1,366	2.6	1,596
Check	8.9	1,103	10.7	1,171	4.8	1,303
Difference required for significance:						
19:1	2.2	n.s.	2.4	150	1.4	210
99:1	n.s.	n.s.	3.3	n.s.	2.0	292

showed that the density of the bean stand may affect the control obtained with DDT dust. Three applications of a 5-per cent purified DDT dust to beans growing in sparse, medium, and dense stands reduced curly top significantly. The yields were increased in all three stands, but best results were obtained in the dense stand. The DDT did not give ample protection to bean growing in a sparse stand.

A 5 per cent purified DDT dust applied to large plots with a power duster in 1950 and 1951 reduced leafhopper populations of seven varieties of susceptible snap beans by 36 per cent. The average yield per acre ranged from 568 pounds for Top Notch Golden Wax to 1,843 for Wade, and all varieties showed increased yields over the untreated plots. The average increase in yield was 72 pounds per acre; the largest increase was 113 pounds for the very susceptible variety Dwarf Horticulture.

Preliminary tests indicated that purified DDT is less likely to damage beans than technical DDT. Therefore, many comparisons were made of the two grades. In 1948 a total of 48 replicates were made in 4 experiments on Bountiful beans using emulsion sprays. Both grades significantly reduced curly top. The average yields were 346 and 344 pounds per acre in the plots treated with purified and technical DDT, both of which were significantly higher than the 280 pounds from the check plots.

In 1949 and 1950 the two grades of DDT were compared in emulsions and 5 per cent dusts in a total of 96 replicates. The purified DDT sprays and dusts reduced curly top an average of 38 per cent and the technical grade sprays and dusts 31 per cent each. Each of the treatments significantly increased yields over that of the check plots. Yields of plots getting 5-per cent purified-DDT dust were significantly higher than those of plots receiving 5-per cent technical-DDT dust.

Table 2 summarizes the results of 4 treatments with the two grades of DDT that were common to 116 replicates in 9 experiments in 1949, 1950, and 1951. There was a tendency for the purified DDT to give the greatest reduction in curly top and the highest increase in yield during these three seasons.

Table 2.—Curly top reduction and yields of Bountiful beans in plots treated with purified-DDT spray and purified- and technical-DDT dusts, 1949–51.

DDT Formulation and Grade	Reduction in Curly Top	Average Yield per Acre	
		Total	Increase Over Check
	Per Cent	*Pounds*	*Pounds*
Emulsion spray, purified	40.9	985	102
Dusts			
Purified 5%	38.8	1,010	127
10%	40.3	1,064	181
Technical 5%	32.9	976	93
Check	—	883	—
Difference required for significance:			
19:1	—	52	—
99:1	—	68	—

SUMMARY.—Six insecticides that had shown promise in the laboratory experiments were tested in the field against the beet leafhopper (*Circulifer tenellus* (Bak.)), the vector of curly top virus, at Twin Falls, Idaho, during the period 1948–52. The objective was to develop a method of direct control of the beet leafhopper on snap beans grown for seed.

Bountiful beans were treated with hand equipment in 22 small-plot experiments, and 7 curly top-susceptible varieties were treated with power equipment in 2 large-plot experiments. Three applications were made at weekly intervals beginning when

the plants were in the "crookneck" stage of growth.

DDT sprays and dusts reduced the percentage of plants infected with curly top more than a CS-674A suspension spray, a schradan emulsion spray, or dusts containing CS-708, methoxychlor, or Q-137 plus DDT.

A 5 per cent purified-DDT dust reduced the curly top infection on sparse, medium, and dense stands of Bountiful beans and increased yields, but it did not give ample protection to beans growing in a sparse stand.

Three applications of a 5 per cent purified-DDT dust with a power duster on seven varieties of snap beans gave a 36 per cent reduction of infected plants. The average increase in yield was 72 pounds of seed per acre, and the largest increase was 113 pounds for the highly susceptible variety, Dwarf Horticulture.

The technical and purified grades of DDT gave about the same reduction in curly top infection, but the purified DDT gave the greater increases in yield of seed.

None of the insecticides gave adequate protection from curly top; therefore this project is being continued to find a more satisfactory insecticide.

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Ventilation of Small Cage Battery[1]

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The problem of caging insects on large numbers of individual small grain plants caused difficulty in maintaining adequate ventilation for good uniform plant growth.

The cage battery described here makes use of a vacuum manifold which serves as a bench. The manifold was made of good quality 1″×8″ S4S lumber. The top and bottom were two boards wide to give an area 15 inches wide and 12 feet long. Cleats of 1″×4″ on the inside at intervals of 2 feet held these boards together. The sides and ends were a single board width and were placed between the top and bottom for support of the top. Wood screws were used in the construction and the seams were calked. A round hole at the center of one side was fitted with a 6.5-inch, 5-bladed electric exhaust fan of the constant operation type used in poultry brooders. A pattern of 35 holes 1-inch in diameter were bored in the top in 3 rows. The holes were spaced to allow good cage shadow distribution by putting 12 holes in each outside row opposite each other with the 11 center holes placed midway between the outside ones.

The plants were grown in quart cans. Each can was fitted with an air tube of ¾-inch outside diameter, the tube running from top to bottom of the can and extending 1 inch above and below the can. The top of the tube was covered by a muslin patch held in place by a rubber band. The lower extension of the tube went through one of the holes in the top of the manifold. The can was filled to within 1 inch of the top with soil. A layer of sand ½-inch deep over the soil served to seal the lower end of the cage which was placed over the plant and the upper tube extension.

The cages were tubes of .01-inch sheet cellulose acetate with tops of muslin. The tubes were 3 inches in diameter and as tall as plant growth required. The muslin tops, which were cemented to the tops of the tubes, were either flat or formed sleeves which could be used for cage access.

There seemed to be very little differnce in air movement through the cages at different locations on the manifold, but replication grouping avoided this effect if it did occur.

A good feature of the system is that individual plants can be removed from the manifold and handled as desired for counts, infestation, or other purposes. A larger model of this cage battery was successfully used by another department at this station.

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Biology of *Meligethes seminulum* Lec.[1]

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The nitidulid beetle, *Meligethes seminulum* Lec., which was originally described from Oregon (Leconte 1857), was scarce until the late 1930's when it appeared in large numbers in red clover fields. The insect is most common in western Oregon, although it has been collected throughout the state. The distribution of the species is discontinuous across northern United States and southern Canada (Parsons 1943). Studies were begun in Oregon in 1949 on life history, biology, control, and the relationships of the insect to red clover seed production.

Description of Stages.—The egg is white, oblong, slightly rough, and is 0.5 mm. long and 0.15 mm. wide.

The larva is yellowish-white, campodeiform, and the mature larva is 2.8 mm. long. The dorsum of the prothorax is light brown along the anterior margin and has four parallel dark bands extending posteriorly. The dorsa of the meso- and metathorax have large dark spots laterally and two small spots medially. The succeeding eight abdominal segments are similarly marked except the medial spots are fused.

The pupa is 2.1 mm. long, yellowish-white, exarate, and lies naked in the upper portion of the soil.

The adult is shiny black, oval, and averages 1.9 mm. long. The antenna has an abrupt 3-segmented club. The elytra are truncate exposing the tip of the abdomen. There are no apparent secondary sexual characters. The adult is described in detail by Leconte (1857) and Parsons (1943).

Life History.—There is one generation a year in western Oregon. The adults overwinter in and around fields in plant debris and protected areas near the soil surface. Spring emergence dates vary slightly, but appear be to coincidental with the first blooming of yellow mustard *Brassica campestris* L., in late March.

The beetles feed on the pollen of plants in bloom. During periods of warm weather they are extremely active and fly readily from flower to flower. Apparently the beetles must feed on pollen prior to mating. Copulation has not been observed less than 4 weeks after spring emergence, and rarely on any flower other than yellow mustard. The mating period is from late April to early June. Adults are found on the unopened buds and racemes of leguminous plants several days before there are any open blooms. Oviposition begins in the basal florets and progresses outward as the flower develops. The eggs are deposited between the calyx and corolla singly or in groups of 2 to 4 eggs per floret. The eggs hatch in 3 to 4 days under laboratory conditions. The majority of eggs are laid in May and June.

Larvae have been found only in the flowers of plants belonging to the family Leguminosae. The probable native host plant has not been determined. Larvae have been recovered from the following legumes: white clover, *Trifolium repens* L.; alsike clover, *T. hydridium* L.; red clover, *T. pratense* L.; bird's-foot trefoil, *Lotus corniculatus* L.; hairy vetch, *Vicia villosa* Roth; and common vetch, *V. sativa* L.

The larvae are very active and crawl from one floret to another within the bloom or raceme. Usually there is one larva per bloom. They are concealed in the corolla, banner, or keel of the developing flowers. Some feeding is done on plant tissue in the undeveloped flowers, but pollen is the major food of the larvae. They remain active in the flowers for 3 weeks. The number of instars is not known. The exuviae are either consumed by the larvae, or are left in inaccessible regions of the flowers.

Larvae may be found in the field from early May until July. The mature larvae leave the florets and drop to the ground. They penetrate from 0.5 to 1.5 inches into the loose soil where they pupate without forming a cell. The naked pupa undulates the abdomen in short writhing motions when disturbed. Under laboratory conditions the pupal stage required 8 to 9 days. The teneral adult is light tan. It requires at least 2 days to harden and transform from tan through reddish-brown to

[1] Technical Paper No. 820 with the approval of the Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

black. Under field conditions the larva probably requires at least 2 weeks to burrow into the soil, pupate, transform, and assume normal adult color.

The majority of adults have emerged by mid-July. Although they may be found on many flowers at this time, the beetles are most numerous on the flowers of legumes. The beetles remain active in the field until early August when they seek their hibernation quarters. An occasional adult may be found as late as mid-September. These beetles are believed to be adults from the previous season which do not hibernate a second winter, or new adults which emerged late in the season. Since there is an abundant source of flowers at the time the beetles leave the fields it is quite possible that hot weather forces them into aestivation, and they remain for hibernation without a fall activity period.

DAMAGE.—Feeding habits and damage studies have been conducted on red clover. Since red clover requires insect pollination, it is extremely difficult to study seed production under laboratory conditions. Damage caused by the larvae is not significant in red clover seed production since the first blooms are clipped for hay in early June. The blossoms which form the seed crop appear in July. The newly emerged beetles cause considerable damage to this second crop of red clover blossoms. The insects force their entrance into unopened buds and feed on pollen and developing floral parts. Although they feed largely on anthers for pollen in the developed flowers, they continue to force an entrance into the small calyx tube. This activity breaks or crimps the style causing it to wither. The resulting browned and ragged flowers are not attractive to pollinating insects. Injured blossoms, which had been damaged by the beetles, were tagged in the field. These blossoms failed to produce seed. Following the application of some of the insecticides, or the migration of the beetles from the fields, the new florets were normal in color and attracted pollinating insects.

POPULATIONS.—A sampling technique was developed similar to that used in sampling pea aphid populations (Gray & Schuh 1941). Clover heads were placed in a funnel, and the adults forced out of the blossoms with a 10-minute exposure to methyl-iso-butyl ketone fumes. Beetles were collected from the funnels in small cartons and killed with carbon tetrachloride. This simple technique permitted large samples to be collected in the field and stored for counting as time permitted.

This nitidulid beetle is another example of a native insect becoming a pest because of a change in agricultural practices. The larval populations develop mainly on hairy vetch and are the source of adults which attack red clover. Population density figures prior to 1949 are not available. From 1949 through 1952 populations were quite uniform, averaging from seven to nine beetles per red clover blossom. In 1953 the average was 15 insects per head, with one field containing 30 beetles per clover head.

There appears to be a relationship between the introduction and increase of hairy vetch and the appearance of the nitidulid beetle in red clover fields. Hairy vetch is the principal present-day host of the immature stages. Its production began in the Willamette Valley around 1928. The acreage rose to approximately 30,000 by the late 1930's, and had increased to 125,000 acres by 1942. This period corresponds to the years the nitidulid beetles first attracted the attention of red clover seed growers. Red clover has been grown in the Willamette Valley since some time in the 1880's. Cultivated acreages of hairy vetch have declined since 1942, but at present hairy vetch occurs in volunteer stands along roadsides and in neglected fields. The high population of the insect during the past few years may be explained by adaptation of the beetle to legume seed culture in the Willamette Valley. The high numbers of beetles in clover fields bordering vetch fields contrasts sharply to the lower populations in isolated clover fields.

CONTROL.—Early in the study a cultural control was investigated by adjusting the cutting dates of red clover hay to destroy the larvae in the blossoms. This approach was not practical since other legumes in the area produced populations which migrated into the clover fields. Insecticides have been applied in July in attempts to control the adults in the clover blossoms. The choice of chemicals is limited by their toxicity to pollinating insects. Because of the insect's migratory habit, period of extended emergence from

the soil, and habit of remaining concealed or protected in the floret, chemical control has been difficult. When field populations were low toxaphene proved the most effective insecticide of those evaluated. When nitidulid populations were over 12 beetles per blossom none of the materials tested gave a satisfactory control and fields were reinfested within 5 to 8 days.

SUMMARY.—The nitidulid beetle, *Meligethes seminulum* Lec., reduces red clover seed production in western Oregon. The adults damage the florets and cause the blooms to become brown and unattractive to pollinating insects.

Adults overwinter near the soil surface and emerge in early spring. Larvae mature primarily in the blossoms of hairy vetch, although they also develop in the blossoms of other vetches, of clover, and of bird's-foot trefoil. Pupation is in the soil. Adult insects feed on pollen of most plants in bloom. There is one generation a year.

Because of the extended migration of adults from vetch to clover, and hazard of insecticides to pollinating insects, a satisfactory chemical control program has not been established.

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Resistance to Insecticides as a Factor Influencing the Biotic Potential of the House Fly[1]

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The rapid development of resistance in the house fly, *Musca domestica* L., to the action of DDT and a number of other insecticides in the past 6 years has created an alarming and complicated problem for entomologists, public health officials, and others deeply interested in the control of this notorious disseminator of numerous disease organisms.

One of the outstanding handicaps to scientists in their efforts toward solving this problem is the paucity of information of the factors which determine the biotic potential of normal and resistant house flies. Aside from the general information on normal flies summarized by West (1951), the published information on this subject is surprisingly scant and contradictory. The present study is aimed at filling a part of this gap.

HISTORY.—In considering the heterogeneous nature of various strains of flies, Decker & Bruce (1952) showed that by selecting unrandomized groups of eggs from each of five DDT-resistant strains they were always able to produce colonies or sub-strains manifesting as high as 50 per cent variation in their susceptibility to DDT. They also found that colonies or substrains produced from the first eggs deposited exhibited far less susceptibility to DDT than colonies produced from the eggs deposited 1 to 2 days later.

Pimentel *et al.* (1951) found no significant differences when they compared the longevity, preoviposition period, incubation period, rate of hatchability, and sex ratio of a susceptible strain obtained from Geigy Company with a highly resistant strain developed from a field-collected strain (Tompkins County, N.Y.). However, in comparing several strains, they found that the number of days required for the completion of larval life was much longer in three resistant strains than in a susceptible strain. These differences were significant at the 1 per cent level. The peaks of pupation in three strains with various levels of resistance to DDT revealed statistically significant differences with respect to the time of occurrence. The susceptible strain pupated first and

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the resistant strains pupated in the order of their resistance to DDT.

In contrast Gagliani (1952) found an average of almost 7.0 days for the duration of larval life of a strain resistant to DDT, and an average of 7.5 days for a susceptible strain at a temperature of 25 ± 2 degrees C.

Several other contradictory results were reported by Barber *et al.* (1948), La Face (1948), March & Lewallen (1950), Noerdinger (1951),[3] and Babers *et al.* (1953), in connection with the biotic potentialities of susceptible and resistant flies.

MATERIAL.—The initial colonies used in this study were obtained as subcolonies of strains maintained by the Illinois State Natural History Survey. In the first few tests one susceptible and four resistant strains were used. It was then decided that making all comparisons against a single susceptible strain was probably invalid, and two more susceptible strains were added to the series. As will be seen later, this change was indeed fortunate. The susceptible and resistant strains were respectively designated by the letters "S" and "R." S-1 was obtained from the original stock developed and distributed by Dr. Frank C. Hazard in 1950. S-2 was originally a wild strain collected in the field in 1949, at which time it displayed a moderate degree of DDT resistance. By selecting the earliest emerging adults for several generations, the S-2 strain was developed to a point where, for all practical purposes, it did not manifest any resistance. S-3 was originally obtained as a fair representation of the 1948 NAIDM stock. The tolerance manifested by the resistant strains was as follows: R-1 resistant to pyrethrins, R-2 resistant to lindane, R-3 highly resistant to most of the chlorinated hydrocarbon insecticides, and R-4 highly resistant to DDT.

METHODS.—Some new equipment and methods had to be designed and adapted to serve the experimental purposes. The cages used for oviposition and feeding purposes were made of cylindrical gallon-size paper cartons, fig. 1(a). An 80×40 mm. square was cut in the lower section of the wall of the can as an entrance, and a 140×75 mm. piece of cardboard, held in place over the entrance by three narrow rubber bands, served as a door for the cage. The rubber bands were stapled to the walls of the can in such a way as to maintain a tension that would quickly pull the door back into place, and thus prevent flies from escaping.

A shell vial 35 mm. in diameter, cut to 20 mm. height and two-thirds filled with milk was fitted with a circle of sheet cork which floated on the surface, fig. 1(b). The cork made it possible for the flies to feed without drowning, since the milk was available to them only in the narrow space between the cork and the shell vial wall. The floating cork was also used as an oviposition site.

The eggs were washed from the oviposition sites into a large pan and then washed onto a 149 micron mesh screen for counting.

For hatchability counts, eggs were placed on a 9.00 cm. #1 Whatman filter paper in the bottom of a pint size fruit jar to which $1\frac{1}{2}$ ml. of milk was added, fig. 1(c). These jars, which were covered with Kerr type metal tops, maintained a desirable uniform moisture content and prevented the larvae from escaping. After removing the filter paper, adding the larval media, and replacing the metallic lid with paper towelling, the same jars were also used for larval life and pupation studies, fig. 1(d).

Snedecor's (1938) method was followed for analysis of the data.

HATCHABILITY.—By employing four series of tests with six replicates each, hatchability differences between strains having a fair degree of significance were obtained, table 1. It was obvious, however, that the significant differences observed could not be correlated with or attributed to either susceptibility or resistance. A highly significant difference noted between R 1 and all other strains was outstanding. The range of variability in the series of susceptible and resistant strains was about equal, and except for R-1 there was almost a complete over lapping of these ranges.

LARVAE.—When 25 newly hatched larvae of the various strains were placed upon media in a series of replicated tests, the number reaching the pupal stage was somewhat variable, and the results were

[3] Noerdinger, Guy John, 1951, Comparative life cycles of normal house flies and house flies resistant to insecticides. Unpublished Master's Thesis, University of Illinois, Urbana.

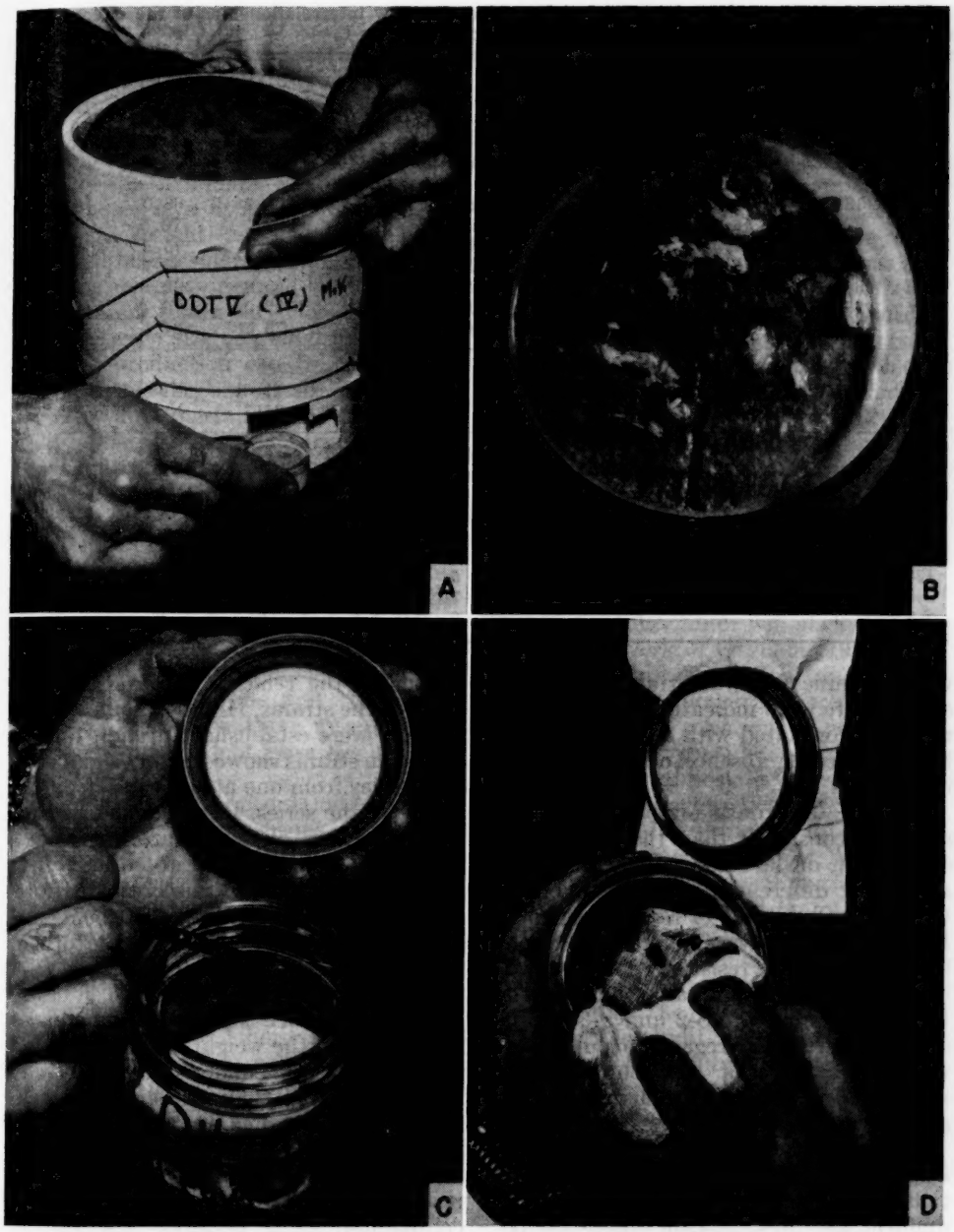

FIG. 1.—Equipment: (a) Oviposition and longevity cage (side view); (b) Feeding vial (top view), showing the floating cork holding eggs and flies in search of food and oviposition site; (c) Jar with metal cap used in egg hatchability tests; (d) Jar with paper towel cover (top view), showing the pupation site between the folds of the cheesecloth on the larval media.

so inconsistent that even with six tests, four replicates each, making a total of 24 replicates for each strain, it was impossible to establish significant differences between strains, table 1. There are, however, apparent differences which approach the magnitude of significance, and, in general, the tendency toward high or low survival ratings seems to follow the pattern set in hatchability and pupal survival ratings,

Table 1.—A summarization of some mean values to show interrelationships of the effect of resistance on the biotic factors of the house fly, *Musca domestica* L.

Strain	Eggs per Female	Weight in Mg.			Adult Longevity (Days)		Per Cent Survival		
		Normal Pupae	Dry Adults				Egg Hatchability	Larvae	Pupae (6×10)
			Female	Male	Female	Male			
S-1	139.0	13.30	3.28	2.77	22.5	17.0	65.2	68.0	82.9
R-1	229.7	15.72	2.62	2.09	25.5	13.8	33.7	70.5	77.9
R-2	259.2	17.53	4.78	3.23	27.7	15.1	68.0	75.2	88.9
R-3	359.4	18.74	4.39	3.27	28.2	19.6	73.5	84.7	83.3
R-4	387.2	18.47	4.67	3.13	28.5	19.6	59.2	82.2	89.2
S-2	390.8	17.45	6.21	3.43	32.3	23.4	79.0	76.7	91.7
S-3	468.2	20.01	4.95	3.45	30.8	23.0	73.7	82.5	95.4
L.S.D.									
1–19	97.16	.82	0.59	0.18	5.9	2.4	11.6	None	9.3
1–99	130.85	1.10	0.79	0.24	7.9	3.2	35.7	None	12.5
		Rating of above, lowest 1, highest 7							
S-1	1	1	2	2	1	3	3	1	2
R-1	2	2	1	1	2	1	1	2	1
R-2	3	4	5	4	3	2	4	3	4
R-3	4	6	3	5	4	5	5	7	3
R-4	5	5	4	3	5	4	2	5	5
S-2	6	3	7	6	7	7	7	4	6
S-3	7	7	6	7	6	6	6	6	7

where significance was established. Here again, there is no indication that survival rates are correlated with or influenced by the presence or absence of resistance to insecticides.

PUPAE.—The data on pupal survival are more consistent than the comparable data taken on larval survival, and some significant differences are established, as the analyzed data of 24 replicates reveal. Here again, however, differences cannot be attributed to resistance or susceptibility. The S-1 strain ranks next to the bottom, whereas the S-2 and S-3 strains rank at the top in regard to pupal survival, and three of the four resistant strains fall in between the susceptible S-1 and S-2 strains.

Data on the duration of the pupal stage, like the data obtained on the duration of the larval stage, are remarkably uniform, and no significant differences between susceptible and resistant strains were established. However, in spite of the fact that 24 hour observations were inadequate for establishing small differences, early emergence was manifested by both males and females of S-1 and S-2 and in general the resistant (R) strains tended to have the longer pupal periods.

Twenty-four lots of 10 pupae each for each of the seven strains were weighed to determine the relative size and perhaps vigor of the strains. Highly significant differences were established; in fact, four of the seven strains showed highly significant differences from one another and from all others in the series. Here again, however, the differences obviously are not associated with or attributable to either resistance or susceptibility. Susceptible strains appear at the two extremes, S-1 being the smallest and S-3 the largest, the others falling in between, with R-2 and S-2 showing no significant difference.

ADULTS.—Since significant differences were noted in the weights of the pupae of the various strains under study, it seemed highly probable that similar differences might be established for the weights of adult flies. For this purpose six lots of 10 air-dried flies were weighed. In general the results obtained are in agreement with the comparable data obtained for pupae, table 1.

Egg production per female for the various strains shown in table 1 was reasonably consistent through six replicates, and highly significant differences were established between strains, but egg production could not be correlated with resistance or susceptibility. Here again susceptible strains occupied both of the extreme positions and there were no significant dif-

ferences between the S-1 and R-1 or the S-2, S-3 and S-4 strains.

CORRELATION.—In studying the summarization of all of the data obtained, such as that presented in table 1, one cannot help being impressed by the fact that vigor is the dominant factor regulating most phases of a fly's life and biological reponses. Weight and adult longevity may well be considered as important criteria of a strain's vigor and hardiness, and it is apparent that a very close correlation exists between size or weight and longevity. Egg production can be closely correlated with either or both size and longevity. The data pertaining to the hatchability of eggs and the survival of the larval and pupal stages also show a fair degree of correlation with size and vigor. In comparing the data on egg production with some of the other pertinent data presented in table 1, correlation co-efficients were obtained as follows: Pupal weight 0.929, longevity of adult females 0.902, larval survival 0.870, pupal survival 0.741, weight of adult females 0.717, and hatchability 0.469. The first three were significant, the latter three were perhaps indicative but did not pass the test for significance.

DISCUSSION.—It appears that the house fly is highly heterogeneous for many characters. Since the inheritance of many of the characteristics of the species may be modified by independent factors where there are six pairs of chromosomes, as in the house fly, the number of potential combinations is tremendous.

Assuming that resistance to insecticides is a multiple factor inheritance and that the various contributing genes may be spread over all six pairs of chromosomes, it should be possible to develop strains of resistant flies with all sorts of correlations for other characteristics such as size, vigor, fecundity, longevity, length of life cycle, etc. That is apparently just what has happened and may continue to happen with varying degrees of frequency. It is apparent throughout most of the data presented that susceptible strains may represent the extremes for all of the characteristics mentioned and likewise resistant strains also seem to cover most of the range. S-1 and R-1 are rarely significantly different from one another for any characteristic except resistance; also, S-3 and R-4 rarely show any significant differences except resistance. It is not surprising, therefore, that workers comparing one or more strains of resistant flies with one susceptible strain would arrive at conflicting conclusions as to the effect of the acquisition of resistance upon one or more unrelated characteristics. It appears that the inheritance of resistance and the other characteristics studied are quite independent, and apparent correlations and divergences may be largely a matter of chance. Even the findings of Pimentel *et al.* (1951) could be explained on this basis, for it is possible all of the strains collected in New York have a more or less common ancestry. As Decker & Bruce (1952) have shown, in some cases where resistance and susceptibility are associated with the length of larval life, it is possible to fractionate a strain for both earliness and susceptibility or lateness and resistance, by inbreeding the earliest or latest emerging adults. There is no evidence, however, that this coinheritance will always occur; in fact, the work of Gagliani (1952) indicates that this correlation may be reversed. It seems possible, therefore, that through proper selection of characters from many sources one might develop strains having almost any desired combination of characteristics.

Perhaps the most significant development in this investigation is the strong correlation that is evident between size, longevity, fecundity, and the other characteristics related to vigor.

The information available is not adequate to indicate clearly whether or not reversion from the resistant to the original or susceptible condition might be expected if the use of the residual type insecticides were discontinued. Other conditions being equal, if resistant flies have a longer life cycle, as was indicated by Pimentel *et al.* (1952) and Decker & Bruce (1952), one might expect the susceptible flies to outnumber and eventually replace the resistant flies. On the other hand, the work of Gagliani (1952) indicates that the opposite trend might be possible. Data obtained in the present study indicate either condition might prevail, depending upon the presence or absence of inheritable characteristics other than resistance. Equally important, however, is the apparent fact that egg production, which might vary as much as 200 to 300 per cent, and is more closely related to vigor

than to resistance, might completely overshadow minor differences in the length of the life cycle in establishing population trends. Perhaps there is a ray of hope in the work of Pimentel *et al.* (1952), inasmuch as their field-collected strains may more truly represent conditions in the field than do the laboratory-developed strains used in this and other investigations. At the same time, the data on annual field surveys obtained by Decker & Bruce (1952) tend to show that the prevalence and intensity of DDT resistance in the field continued to increase even after the use of DDT was greatly curtailed. Much additional work with field-collected strains will be required to develop answers to today's questions.

SUMMARY.—Laboratory studies were conducted to determine what influence, if any, the acquisition of resistance to chemicals might have on the various factors that combine to determine the biotic potential of the house fly, *Musca domestica* L. Seven strains of flies, three having normal susceptibility to insecticides and four possessing a high degree of resistance to one or more insecticides, were included in the study.

The response of various strains may be summarized as follows:

Strain S-1, developed from the CSMA laboratory strain, showed no resistance to insecticides, ranked at the bottom of the list (lowest) for egg production, pupal weight, longevity of females and larval survival; second from the bottom for weight of adult male and female, and pupal survival.

Strain S-2, a selection from a field collection, showed no resistance to insecticides, ranked at the top (highest) or next to the top of the list for egg production, weight of adult flies, longevity of both males and females, egg hatchability, and pupal survival.

Strain S-3, a selection from the NAIDM 1948 laboratory strain, was not resistant to insecticides, ranked at the top or next to the top of the list for all characteristics studied.

Strain R-1, which was highly resistant to pyrethrins and moderately resistant to DDT and lindane, was not significantly different from the susceptible S-1 strain and ranked at or next to the bottom of the list for all of the factors associated with vigor.

Strain R-2, highly resistant to lindane and moderately resistant to DDT, maintained an intermediate position, usually ranking third or fourth for all of the factors associated with vigor.

Strain R-3, highly resistant to DDT and Dilan, also maintained an intermediate position, usually ranking from third to fifth for the factors associated with vigor.

Strain R-4, very resistant to DDT, also maintained an intermediate position, ranking third to fifth for most of the characteristics associated with vigor.

The data obtained in all phases of the study tended to show that the inheritance of the factors associated with vigor, such as egg production, pupal or adult weights, longevity of adults, egg hatchability, and the survival of larvae and pupae, were independent of the factors associated with resistance.

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Screening Studies of Chemicals for Larval Control of Blackflies[1] in Guatemala[2]

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Human onchocerciasis, a disease caused by infection with the filarid worm, *Onchocerca volvulus*, was discovered in the Western Hemisphere for the first time by Robles in 1915 (Calderon 1917, Robles 1919). To date, it is known to be endemic only in central Africa and parts of Guatemala, Mexico, and Venezuela. Because of the frequent ocular involvement, often leading to blindness, several studies of the disease, its vectors, transmission, and cure have been instituted. It was Blacklock (1926), working in Africa, who first demonstrated experimentally that flies of the family Simuliidae were the probable vectors of onchocerciasis.

Since 1947, a laboratory for the study of onchocerciasis, sponsored by both the Pan American Sanitary Bureau and the Laboratory of Tropical Diseases of the Microbiological Institute, National Institutes of Health, has been functioning in Guatemala with headquarters in San Pedro Yepocapa, Chimaltenango. This area, from which Robles described the original cases found in the Americas, is ideally suited for the experimental work with the disease since it is actually situated within the upper limit of the largest endemic zone. Members of this project have worked with various drugs from the standpoint of their diagnostic, prophylactic, and curative value; parasitological studies have been made to determine the normal developmental cycle of the filarid parasite in the simuliid vectors; entomologically, the existent species of blackflies in Guatemala have been surveyed, the anthropophilic species determined, and their life history and ecology studied. Due to the difficulty involved in administering the most promising drug on a large scale, (intravenous injections, one per week, for a period of 8 weeks) and because of the marked reactions it causes in the patient, it has been felt that control of the disease vectors would be of greater importance, at least until the present treatment is refined or other drug cures are found.

Based on the information gained from previous investigations, it was felt that studies of chemical control of the Simuliidae should be initiated. Small-scale attempts at adult control from the ground proved not to be feasible because of the characteristic ruggedness of the terrain. For this reason, only investigations concerning larval control have been pursued. The only larval control studies carried out in Guatemala, prior to those herein reported, were published by Fairchild and Barreda (1945). They found DDT emulsions at a concentration of 0.1 p.p.m., poured into streams over a period of 1 hour, to be 100 per cent effective at 10 kilometers. However, the long period of application necessary, and the relatively few trials they were able to make, indicated the need for further studies in order to develop a plan for control in extensive areas.

The study of chemical control of *Simulium* larvae has been divided into two phases: First, a laboratory screening program of both known insecticides and of chemicals of unknown insecticidal value, conducted to determine whether a toxicant could be found which would give more rapid and effective kill of larvae than materials now recommended; second, small-scale field trials of materials which appeared effective in the laboratory screening and the determination of the most economical and effective method of applying them under conditions existing in Guatemala. The present report deals with the first phase.

DEVELOPMENT OF TEST CONTAINER.—Since the natural habitat of the simuliid larvae is in running water (attempts at holding larvae in standing water or at bubbling air or oxygen into the water were of no value), it was necessary to bring to the laboratory buildings a source of fresh running stream water that would be sufficient for testing several chemicals simul-

[1] Diptera, Simuliidae.

[2] Part of a study jointly supported by the Laboratory of Tropical Diseases of the National Institutes of Health, Public Health Service, and the Pan American Sanitary Bureau, in cooperation with the Dirección General de Sanidad Pública of the Republic of Guatemala. The project was aided by a research grant from the National Institutes of Health, Bethesda, Maryland.

taneously. Fortunately, the water supply for Yepocapa is taken from a stream several kilometers above and passes directly into the town through a closed-pipe, gravity system. Although the unfiltered and unpurified condition of the water was an advantage in supplying nourishment to the larvae, the silt present also created considerable difficulties by hindering passage of the water through any type of container used for confining the larvae.

To date, all attempts to establish a self-perpetuating laboratory colony of *Simulium* have met with no success, precluding the possibility of having a constant laboratory source of uniformly reared larvae for testing. Although it is possible to rear larvae from eggs in a laboratory canal system, the locating and collecting of egg-masses throughout the year to supply adequate quantities of larvae for the number of tests contemplated, would require a staff much larger than practicable. Thus, it was decided to use larvae collected directly from the streams in the vicinity of the laboratory.

Since it was soon observed that the larvae were too fragile to withstand more than a minimum of handling, it was necessary to develop a testing technique using a single container in which the larvae could both be tested and then held until mortality counts were made. This would eliminate the necessity of transferring the larvae to special holding containers. Although Vargas (1945) using aquaria and Thomas (1939) using a series of baffles were able to rear simuliids from eggs to adults, the large size of these systems precluded their use as test containers for screening tests. Several months of experimentation were required before a system was developed, suitable for maintaining the larvae alive for a reasonable period after testing, and yet using test containers which were small enough to make large-scale screening practical. In their natural habitat, the larvae are generally found attached to vegetation or rocks so close to the surface of the water that their bodies almost break through the surface film. Therefore, several test containers were designed in which the larvae were covered by only a thin film of running water. The major difficulty was to find a method by which the larvae could satisfactorily be confined (they normally tend to migrate) and at the same time, one that would permit the free passage of continually running water. Material, gauze or wire screen, fine enough to prevent the escape of the larvae would soon clog with dirt and silt from the water and cause the container to flood, with resultant death of the larvae; coarse materials, naturally, would permit the larvae to work their way through the mesh. Grade 80 cheesecloth was finally used as a compromise between the two extremes. To implement the efficacy of the system further, an additional piece of cheesecloth was added at the entrance of each test container to serve as a "filter" for the incoming water. With the equipment finally developed, it was possible to test the larvae and hold them approximately 48 hours without excessive mortality due to the testing technique, as shown by the untreated checks. This short survival period probably resulted from the size of the container and the relatively small volume of water entering it.

The most suitable container consisted of a 3-inch length of glass tubing, open at both ends, having a 1-inch inside diameter. One end was covered with a piece of grade 80 cheesecloth held in place by a rubber band, the other end remaining open at the beginning of the tests (Fig. 1-A).

TESTING PROCEDURE.—Vegetation to which larvae were attached was collected from nearby streams and brought to the laboratory in dampened pillowcases. The larvae were individually removed from the vegetation with forceps and placed in a pan of shallow (approximately $\frac{1}{4}$-inch) water (Fig. 2-A). In about 15 minutes, when the pan became well stocked, the larvae were counted into testing containers, 25 per tube (Fig. 1-B). This was done by means of a large rubber-bulb syringe which could be used to suck up several larvae at one time. The gauze-covered glass tube test container, having been placed in a paper cup which served to hold the water expelled from the syringe during the counting, could then be lifted out, draining the tube, and leaving the larvae clinging to the gauze across the bottom. In this manner, the larvae were "strained" so that no excess water was carried over to dilute the test solutions.

After preliminary tests with DDT and several other insecticides, it was determined that for screening purposes, dilutions of 10 p.p.m. and 1 p.p.m. would be

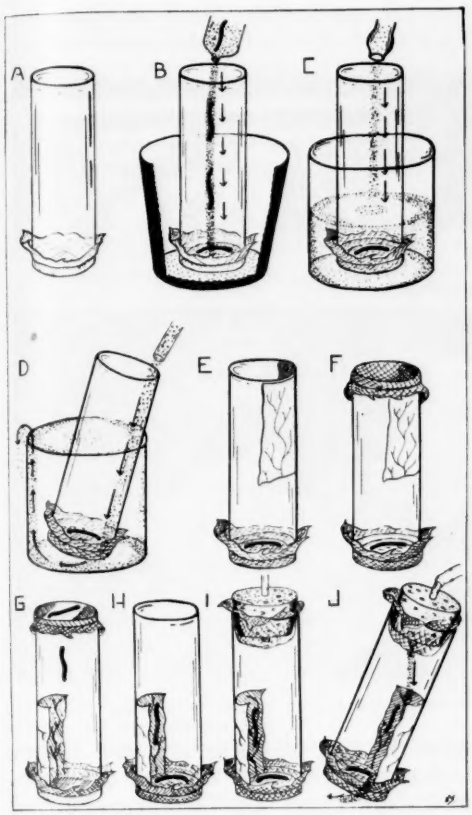

FIG. 1

used and the exposure period of the larvae to the test chemical would be 30 minutes. Three tubes, containing 25 larvae each, were exposed to the test chemical at each of the two concentrations. Each of the testing tubes was placed in a 2-ounce, wide-mouthed jar so that the gauze-covered end with the larvae was submerged to a depth of about one-half inch in the test solution, where it was left during the 30-minute testing period (Figs. 1-C and 2-B). While one test group was being exposed to the chemical others were being prepared for the treatment.

A one per cent stock solution of each chemical was prepared and then diluted with water to the desired concentration. Solvents for the chemicals presented considerable difficulty. The following, when tested without toxicant at 10 p.p.m., caused too high a mortality rate to be used in tests with chemicals of unknown toxic properties: Xylene, 25% xylene-75% acetone, kerosene, benzene, toluene, α-methylnapthalene, cyclohexane, acetic acid. Only acetone, ethyl alcohol, methylene chloride, and $NaHCO_3$ were non-toxic to the larvae when diluted alone to 10 p.p.m. Those compounds found to be insoluble in these solvents were prepared and tested as suspensions in acetone with the addition of a few drops of Triton-X-100.[3] Whenever chemicals were tested, several tubes of larvae were exposed for 30 minutes to a dilution of acetone identical to that in a test chemical but omitting the toxicant.

At the end of the 30-minute exposure period, the six tubes used for any one test chemical were removed from the solution and placed in another set of clean jars of the same size. Each of these was arranged under a jet of water. Since the testing container was much higher than the edge of the jar, the water was made to enter the container, passing through the gauze at the bottom, thus filling the jar and passing out over the rim (Fig. 1-D). This assured a complete circulation of the water through the tube of larvae and provided a good "rinsing" to remove any excess chemicals from the container and the larvae. The tubes were left in the rinse 15-20 minutes or while previously rinsed tubes were being prepared for the holding period.

Various trials showed that survival was increased if a piece of leaf was introduced into the test container so that the larvae could attach to it rather than to the glass wall of the container itself. Therefore, immediately after removal of the test containers from the rinse, a piece of leaf, about 1.5 inches by 0.75 inch, was inserted, one edge flush with the upper lip of the tube (Fig. 1-E). Over this upper end a clean piece of the 80 mesh cheese cloth was fixed in place with a rubber band (Fig. 1-F). The tube was then inverted and the larvae clinging to the old gauze were washed off and down onto the clean piece by means of a jet of water from a syringe (Fig. 1-G). The old gauze, which had been contaminated by the test chemical, was removed and discarded (Fig. 1-H). A second clean gauze was then loosely placed over the open end, and finally, a cork, through which a short length of glass tubing had been inserted, so as to protrude from both ends, was

[3] Supplied by Rohm & Hass Company.

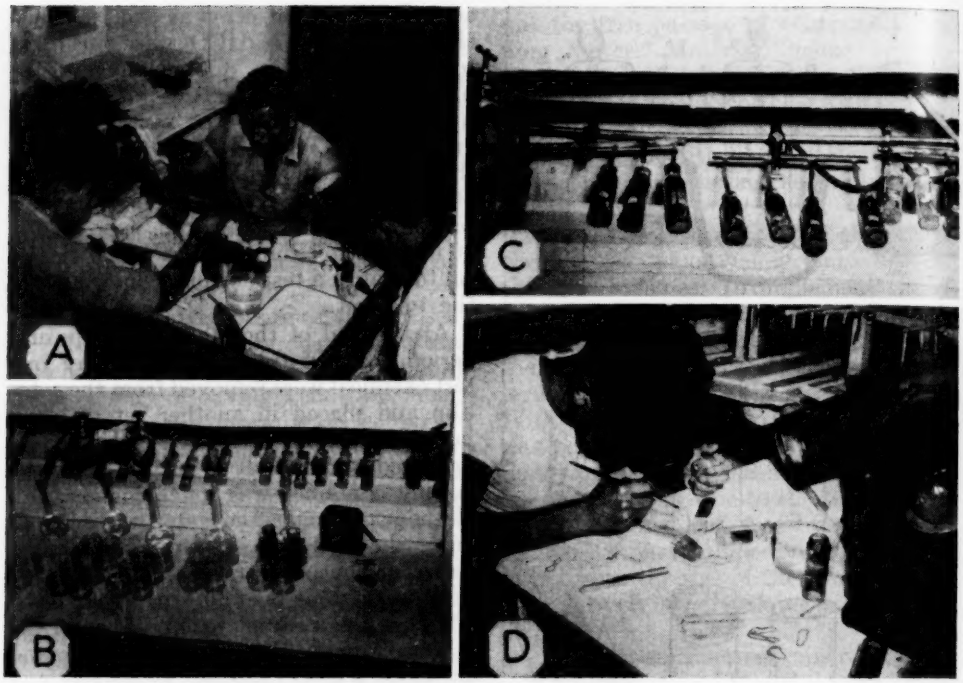

FIG. 2

fitted into the same end over the gauze (Fig. 1-I).

The testing laboratory was equipped with over a dozen faucets and the water supply from each of these was further subdivided by attaching to each faucet a length of copper tubing with 8–12 outlets, thereby giving a total of some 150 water outlets. Each test container, with its enclosed larvae, was prepared for holding in the manner just described, and the glass tubing extending from the cork in each test container was connected to one of the indvidual outlets by means of rubber tubing. The outlets were arranged several inches above and slightly behind a metal drainage canal so that the connected test containers would have their lower ends resting on the canal, thereby being inclined at a 45° angle (Fig. 1-J).

During the entire holding period, a continuous stream of water entered the test containers. The loosely placed gauze at the upper end of the container of larvae served to filter out larger particles of dirt and debris as well as to prevent larvae from escaping by ascending through the glass tube and thence into the water delivery system. The water which entered the inclined tube passed, in a thin film, over the leaf with the attached larvae, and out of the tube through the gauze at the lower end. The metal canal served to carry off the water from all tubes (Fig. 2-C).

Because mortality would begin to appear by 48 hours in tubes containing untreated larvae, the holding period was terminated after 36 hours when the natural mortality was negligible. To make mortality counts, each tube was disassembled, all the larvae removed, and the number of dead, surviving, and those which had pupated, recorded. The larvae were then discarded as they were too fragile to return to the tubes without mortality due to handling.

Since larvae inevitably escaped from some of the tubes, mortality counts could not be made simply by taking the percentage dead of the original 25 larvae that had been placed in each tube. Thus, it was necessary to count both the dead and living larvae in order to ascertain for the particular tube the total number to be used in determining percentages. The persons making the counts were equipped with a tally counter in each hand, one to record dead larvae, the other to record the living. Each larva was touched with

a camel's hair brush while being observed for movement through a loupe, movement being the criterion for survival (Fig. 2-D). The number of larvae which had pupated was also recorded, and since, in the following tables only percentage mortality is recorded, pupation was incorporated in the survival figure.

RESULTS.—It is obvious that there are certain limitations inherent in this method of testing which would make it difficult to obtain consistent results from day to day; hence, the results indicate only relatively the toxicity of the different products tested. However, the 10 p.p.m. dilution was high enough to point out all good materials, while 1 p.p.m. was low enough to indicate the relative toxicity of the materials, using DDT as a standard for comparison. Any compound showing promise was retested along with DDT at concentrations intermediate between 10 p.p.m. and 1 p.p.m. and lower than 1 p.p.m., as well as for exposure periods shorter than 30 minutes.

Table 1A.—Laboratory tests[1] conducted during the rainy season with ten compounds against larvae of *Simulium downsi*.

COMPOUND	CONCENTRATION IN P.P.M.	TOTAL LARVAE[2]	AVERAGE PER CENT MORTALITY
DDT	10	91	96.3
	1	90	42.0
EPN[3]	10	90	100
	1	81	100
Dieldrin[4]	10	100	95.9
	1	92	93.5
Aldrin[4]	10	89	82
	1	95	76.6
Heptachlor[5]	10	96	82.3
	1	94	49
Chlordane[5]	10	102	77.3
	1	91	32.6
Methoxychlor[6]	10	98	73.6
	1	71	57.2
Lindane[7]	10	84	58.5
	1	95	26.4
Toxaphene[8]	10	96	24.9
	1	90	13.2
TDE[9]	10	87	21.8
	1	65	18.9

[1] Exposed for 30 minutes to dilutions as indicated.
[2] Four replicates of 25 larvae per tube; total larvae at the end of 36-hour holding period recorded. Flow of fresh water continuous throughout holding period.
[3] Obtained as test material from National Research Council, Chemical Biological Coordination Center, submitted by E. I. Du Pont de Nemours & Co.
[4] Julius Hyman Co.
[5] Velsicol Corp.
[6] E. I. Du Pont de Nemours & Co.
[7] Ethyl Corp.
[8] (40% Wettable Powder) Hercules Powder Co.
[9] (50% Wettable Powder) Miller Chemical & Fertilizer Corp.

Table 1B.—Laboratory tests[1] conducted during the dry season with thirteen compounds against larvae of *Simulium downsi*.

COMPOUND	CONCENTRATION IN P.P.M.	TOTAL LARVAE[2]	AVERAGE PER CENT MORTALITY
DDT	10	70	100
	1	66	78.5
Methyl Parathion[3]	10	67	100
	1	75	100
Metacide[4]	10	70	100
	1	65	100
Parathion[5]	10	78	100
	1	64	97
Sulfotepp[6]	10	73	100
	1	72	91.6
TEPP[6]	10	73	100
	1	66	55.3
Malathion[5]	10	68	95.6
	1	64	77.1
CS-645A[7]	10	71	95.9
	1	70	90.4
CS-674A[7]	10	74	15.5
	1	71	8.9
CS-708[7]	10	77	68.8
	1	76	21.9
Compound 923[8]	10	72	58.2
	1	65	29.3
Schradan[6]	10	68	34.1
	1	59	20.4
Aramite[9]	10	63	22
	1	65	19.9

[1] Exposed for 30 minutes to dilutions as indicated.
[2] Three replicates of 25 larvae per tube; total larvae at end of 36-hour holding period recorded. Flow of fresh water continuous throughout holding period.
[3] Chemagro Corp.
[4] Dow Chemical Co.
[5] American Cynamid Co.
[6] Monsanto Chemical Co.
[7] Commercial Solvents Corp.
[8] Allied Chemical and Dye Co.
[9] Naugatuck Chemical Division.

In addition to the test materials obtained regularly by the National Institutes of Health through the cooperation of the Chemical-Biological Coordination Center of the National Research Council, samples of a number of insecticides and test materials were supplied directly by their manufacturers. The results of tests with those compounds showing larvicidal activity are given in table 1-A and table 1-B. In all, over 800 chemicals were tested in the laboratory by the technique described.

Since EPN, dieldrin, DDT, and lindane were available at the beginning of the work, they were further tested at 10, 2, 1.0, 0.5, and 0.2 p.p.m. for exposure periods of 30, 15, 5, 2, and 1 minutes. The resultant data are given in table 2. Mortality counts were made 36 hours

Table 2.—Laboratory tests[1] with four compounds against field-collected *Simulium downsi* larvae.

P.P.M.	Insecticide	Average Per Cent Mortality of Two Replicates				
		Exposure Period in Minutes				
		30	15	5	2	1
10	EPN	100	100	100	100	100
	Dieldrin	100	100	100	67.8	53.3
	DDT	100	84.5	68.2	17.9	29.6
	BHC	79.2	90.4	58.7	40.2	51.8
2	EPN	100	100	100	93.5	61.0
	Dieldrin	100	100	100	50.0	41.6
	DDT	78.4	65.5	62.8	24.0	27.6
	BHC	66.7	40.0	62.9	43.2	30.6
1	EPN	100	97.5	83.7	82.5	33.5
	Dieldrin	96	97.6	100	56.9	26.2
	DDT	53.2	52.4	40.0	23.4	32.2
	BHC	51.5	32.3	41.7	34.7	—
.5	EPN	100	97.8	37.6	34.9	—
	Dieldrin	89.3	92.5	87.5	64.4	27.5
	DDT	47.8	26.9	—	—	—
	BHC	39.1	33.5	—	—	—
.2	EPN	100	90.4	27.1	—	—

[1] Two tubes of 25 larvae for each combination of concentration and exposure of the four insecticides. Flow of fresh water continuous during 36-hour holding period.

after treatment, using two replicates for each exposure-concentration combination.

Discussion.—In the laboratory the various compounds containing phosphorus (i.e. methyl parathion, EPN, parathion, sulfotepp, and Metacide) were found to be approximately equal in toxicity with the exception of malathion. Heptachlor, chlordane, dieldrin, DDT, aldrin, and TEPP also were found to be toxic, although less so than the "phosphorus compounds" under laboratory conditions. Lindane, toxaphene, methoxychlor, TDE, schradan, CS-674A and CS-708 were less toxic than the others in the laboratory.

In addition to these chemicals of known insecticidal value, several of the other test materials which were screened were found to be toxic. They were:

Quinoline, 8-phenylmercurioxy-
Ethane, 1,1,1-trichloro-2,2-bis(p-fluorophenyl)-
Copper Pentachlorophenate
1,4-Naphthoquinone, 5,8-dihydro-
m-Cresol, 6-*tert*-butyl-2,4-dinitro-

However, none of these materials are as effective as EPN, methyl parathion and Metacide.

It was noted over a year period that the "reaction" of the larvae to test materials varied with the change of seasons. This was especially evident in tests with DDT, which was generally more effective during the dry season than during the rainy season. This probably can be explained as being the result of a process of "natural selection" of larvae that is manifest during the rainy season. At this part of the year, the torrential rains loosen the weaker larvae from their anchorage, killing them by mechanical action. Only the stronger, more resistant larvae remain, and it was these that were used for laboratory testing. During the dry season, when there is virtually no rain, this "selector" was not acting, so that weak larvae as well as strong larvae were collected for experimental use. These fluctuations serve as an additional reason why the laboratory tests cannot be used as more than a guide to effectiveness.

In field tests, results of which will be subsequently published, it was found that in the streams serving as breeding places for the principal anthropophilic species of blackflies in the Municipality of Yepocapa, a much lower concentration of DDT EPN, dieldrin, aldrin, heptachlor, and chlordane applied for a shorter period of time is effective in completely clearing these streams of larvae, whereas in the laboratory, even at 1.0 p.p.m., all but EPN in table 1-A and all but methyl parathion and Metacide in table 1-B produced less than 100 per cent mortality. Therefore, it can be seen that the results obtained in the laboratory are not a direct indication of effective field concentrations but rather a general guide to toxicity.

Summary.—A laboratory method is described for screening chemicals against simuliid larvae in small glass tubes, 1 inch in diameter and 3 inches long. Field-collected larvae are exposed to a water dilution (10 p.p.m. and 1 p.p.m.) of a 1 per cent stock solution of the test material for 30 minutes. After exposure the excess material is "rinsed" off and the tubes of larvae prepared for a maximum holding period of 36 hours at which time mortality was recorded. Some 800 materials were tested by the technique along with various well known insecticides.

EPN, methyl parathion, parathion, Metacide, sulfotepp, were found to be the most toxic materials in the laboratory. Heptachlor, chlordane, aldrin, dieldrin, DDT, and TEPP were also effective in these tests. The laboratory results concur with field trials of the materials, but a much lower concentration and applica-

tion time was required in the breeding streams. The laboratory tests, however, served to sort out effective materials and provide a general ranking of toxicity.

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Life History and Habits of a New Seed Midge, *Dasyneura gentneri* Pritchard[1]

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In July, 1950, a seed midge which was heavily attacking a Ladino clover seed crop was found by the writer in the Evans Creek area of Southern Oregon. Because of its similar appearance this insect was thought to be the clover seed midge, *Dasyneura leguminicola* Lintner. Preliminary life history observations, however, showed that the habits of this midge were different from those reported for the clover seed midge on red clover (Creel & Rockwood 1947). Furthermore the clover seed midge had not been reported from Ladino clover, and had been reported to attack white clover and alsike clover only rarely and in small numbers (Creel & Rockwood 1947). Specimens were sent to Dr. A. E. Pritchard, University of California, who found them to represent a new species which he has named *Dasyneura gentneri* (Pritchard 1953). In this paper this midge will be referred to as the Ladino clover seed midge. Preliminary observations were made during the summer and fall of 1950, but most of the observations and experiments were carried out during 1951 and 1952.

DISTRIBUTION AND ABUNDANCE.—The Ladino clover seed midge was found in nine out of 12 Ladino clover fields examined in Jackson and Josephine counties in Southern Oregon during 1951. Infestation of florets examined through July ranged from about 2 per cent to 25 per cent in these fields. Infestation increased through August, and in September nearly 100 per cent of the heads in several fields were infested. Infestation of the florets within these heads ranged from 7 per cent to 75 per cent.

During August of 1952, a limited survey was made of the Ladino clover fields in Jefferson County in Central Oregon. A total of nine fields were examined in the area, all of which were infested with Ladino clover seed midge. A sample of ten green heads was collected from each of four of these fields. An examination of these heads showed that from 78 per cent to 83 per cent of the florets were infested.

This midge was found to be abundant and causing a considerable loss of seed at Prosser, Washington, by E, C. Klostermeyer,[2] Assistant Entomologist, Washington State College. He has also found it to occur at Pasco, Grandview, and Burbank, Washington.

In the spring of 1953, two soil samples of 1 square foot each were taken from an alsike clover field in Jefferson county. One of the samples contained 625 cocoons and the other 672 cocoons, indicating that in at least some cases this midge is also a serious pest of alsike clover.

A simple method to determine infestation in a field is to place a number of clover heads, which are through blooming but are still green, in a paper bag and after

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[2] Personal communication.

about 24 hours examine the bottom of the bag for maggots.

HOSTS.—Ladino clover, *Trifolium repens latum*, was found to be the most common host of the Ladino clover seed midge in all areas investigated. Adults were also reared from larvae that were found infesting alsike clover, *Trifolium hybridium*, in Jackson and Jefferson counties. In all cases the alsike clover was in or near heavily infested Ladino clover fields.

Many heads of red clover, *Trifolium pratense*, were examined from plants growing in or near infested Ladino clover fields. Only three florets were found to be infested, one with an immature midge larva and two with midge eggs. These eggs were located inside the floret, a location similar to that of the eggs of the Ladino clover seed midge as opposed to the external location reported for the eggs of the clover seed midge (Creel & Rockwood 1947). This suggests the possibility that the Ladino clover seed midge may occasionally attack red clover.

The Ladino clover seed midge was not found infesting white clover, *Trifolium repens*, but examinations were limited to closely clipped lawns and pastures which are unattractive to this insect.

SEASONAL HISTORY.—To obtain spring emergence data cocoons were overwintered at the Southern Oregon Experiment Station south of Medford, and at Evans Creek, 25 miles northwest of the Experiment Station. The first adult emerged at the Experiment Station on May 9. From May 9 to May 12, four adults emerged. Seventy-five per cent of the emergence (73 adults) occurred from May 14 to May 20. Scattered emergence continued through June 3. The first adults emerged at Evans Creek about 2 weeks later than at the Experiment Station. This delay undoubtedly resulted from the higher elevation at Evans Creek with its correspondingly lower winter and spring temperatures. Emergence extended over a period from May 24 to June 12, with the bulk of the emergence occurring from May 28 to June 5. Spring emergence in the clover fields nearly paralleled that from the Station insectary. The first adults were taken in the field on May 16, but at that time a few young larvae were already working in the heads, showing that limited activity had begun earlier. The adults were most numerous from May 19 to May 27, after which there was a gradual decline. Only occasional individuals were found when the clover in the field under observation was cut during the week of June 16. The first clover blossoms appeared in the field about the first of May. Blossoms were abundant by the time midge emergence became general.

The Ladino clover seed midge was generally active during the summer of 1951 except for a period extending from the middle of July through the first part of August. During this time, although the adults were present in the field, little oviposition was observed and very few young larvae were found. Hot, dry weather prevailed which may have served to limit activity. Midge numbers were highest during the last half of August and early September. During 1952, adults and larvae were found in all examinations made during the period when the clover seed crop was growing.

In fields where a regrowth of clover occurs after the seed crop is harvested, the midge is active until the first heavy frosts. The last adults were found in the field on October 16, in 1951 and on October 28, in 1952. After about the middle of August some larvae go into dormancy and do not transform until the following spring. The percentage of larvae going into dormancy increases through September and very few larvae maturing after the first of October transform in the fall. Out of 25 mature larvae collected on August 18, 14 transformed in September and 11 the following spring. Out of 50 mature larvae collected on September 18, only 6 transformed in the fall.

DESCRIPTION OF STAGES.—The newly deposited egg is smooth, shiny, and nearly colorless. It is elongate in shape, about one-third as wide as long, slightly curved, and somewhat pointed at the anterior end. The shell is fairly elastic and possesses an adhesive quality. The egg gradually takes on a yellowish hue until it becomes a pale orange in color. About 12 to 24 hours before the egg hatches a round, orange spot appears in the center. This spot gradually becomes darker and more concentrated until just before the egg hatches it is a bright red-orange in color. The surrounding portion of the egg at this time is somewhat lighter than it was before the spot developed. The average size of 10 eggs was 0.3260 mm. in

length and 0.0828 mm. in width.

The newly hatched larva is light yellow in color and nearly transparent except for a red-orange spot located toward the anterior end. As the larva increases in size this spot enlarges and becomes lighter in color. The color of the larva deepens from a light yellow to orange and finally to a dark orange or salmon pink. The color changes most rapidly during the last few days of larval development. The body of the mature larva is made up of 13 segments and is somewhat narrowed at both extremities. A spatula, or so-called "breast bone," is present on the mid-ventral portion of the second segment. The spatula is bilobed anteriorly, tapers posteriorly, and terminates in an enlarged globular portion. The head is very small and retractable. It bears a pair of fleshy antennae on its lateral margins which are about one-half as long as the head. The mouthparts are inconspicuous. The average length of 25 larvae was 2.02 mm. ranging from 1.2 mm. to 2.4 mm.

The cocoon is constructed of a tough, silken substance. It is oval in outline, averaging 1.56 mm. long and 0.89 mm. wide. It is lustrous white in color and the surface is irregularly dented and grooved. The cocoon is often partially coated with soil particles or small pieces of ground litter.

The pupa is fusiform in shape, averaging 1.50 mm. in length and 0.71 mm. in width. From the dorsal view the bases of the antennae appear as sharp projections on either side of the head. A pair of slender horn-like spines arises behind the antennae, and a pair of stouter horn-like spines occurs on the lateral margins of the thorax. The newly formed pupa is uniformly orange in color. The appendages, which are folded along the venter of the abdomen, are transparent. The appendages are black in the fully developed pupa. The head and thorax are mostly dark with lighter areas showing through. The abdomen is orange to dark orange with bars of brown scales dorsally.

The adult is a small, delicate, gnat-like fly about 1.5 mm. to 2 mm. in length. The compound eyes are large, covering most of the head. The antennae are long, moniliform, and taper gradually from the base to the apex. The number of segments is somewhat variable but there are usually 15. On each segment there is a whorl of setae which are long in the male and rather short in the female. The antennae of the male have the segments pedicellate and the apical segment is the longest. The thorax is dark brown dorsally and orange ventrally. The wings have few veins and are covered with coarse, brown scales. The legs are extremely long and slender. The abdomen is bright, red-orange in color and is banded dorsally and ventrally with dark brown scales. The abdomen of the female terminates in a four-segmented ovipositor which when extended is longer than the body. The abdomen of the male terminates in a pair of stout claspers.

LIFE HISTORY.—All life history observations were made in Jackson and Josephine counties in Southern Oregon.

Mating.—Adults of the Ladino clover seed midge were often observed in the process of mating. Mating, as well as other activities of the adult, begins at 65 to 70 degrees Fahrenheit. At temperatures above 90 degrees activity is largely suspended and the adults are found resting in the shade of the clover plants. The male, in search of the female, flies among the clover foliage and seems to be particularly attracted to the clover blossoms. When the female is located, the male, with no preliminary courting, grasps the end of the female's abdomen with his claspers. The pair usually remains united in this manner for only a few seconds, but in several instances copulation lasted for at least a minute. Mating takes place at intervals during oviposition. Ovipositing females are often interrupted by the male for the purpose of mating. The female often mates with more than one male. In one case a mating pair was observed on a grass stem, with several other males flying about and two more resting near by. As soon as one male finished mating he was replaced by another until the female had been in copulation with at least four males. At this point the female left the grass stem for a nearby clover leaf. Shortly afterward, several males appeared and investigated the portion of the grass stem previously occupied by the female. None of these males were observed to find the female in her new location.

Oviposition.—The eggs are deposited by the adult female in the open florets of the clover head. Immature florets and those

which have been pollinated and are beginning to dry, are not selected for oviposition. Under field conditions of warm days and normal pollination, a floret remains suitable for oviposition for one or two days. Oviposition may take place before or shortly after pollination. The usual location of the egg within the floret is in the enclosed space at the junction of the filament and one of the wing petals. Rarely, eggs may be deposited on the stigma or on the inner surface of the standard petal. In one instance an egg was found inserted under the sepals.

During oviposition the female straddles the standard petal and faces the outside of the clover head. The ovipositor is thrust upward into the flower parts and is kept in a constant, probing motion until the egg is deposited. The egg is usually deposited in one-half minute or less, but in some cases it may require several minutes. After the egg is laid the female may move to the next floret on either side, or she may pass over several apparently suitable florets before selecting the next one for oviposition. One or two eggs are usually deposited in each floret, but where midge numbers were exceptionally high as many as six eggs were found in a single floret. The number of florets selected for oviposition on any particular clover head varies with the number of suitable florets, and therefore with the size of the clover head. The usual number is from about 2 to 12 florets per head. Because of the poor adaptability of the adult to confinement, the number of eggs deposited by a single female was not determined.

Incubation Period.—The time required for the hatching of 79 eggs observed in June and August ranged from 46 to 62 hours, with an average of 54.4 hours. The average for June was 60.4 hours, and for August 51.4 hours.

Larval Development.—After emerging from the egg the larva moves to the pod where it feeds for a few days near the center, or opposite the point where the egg is laid. Then it moves to the base of the pod and locates itself between the pod and the standard petal. It apparently feeds by sucking juices from the pod. Feeding is localized at first, usually forming a light colored, slightly depressed area over a single seed. Soon, however, the larva feeds from the ventral carpellary bundles which nourish the developing seeds. This feeding is evidenced by the gradual shrinking and collapsing of the seeds, first at the base of the pod, and later at the apex. The seeds in the apex of the pod are often less injured than those in the base.

One pod normally supplies sufficient food for the development of a larva. However, in several instances nearly mature larvae were found feeding on pods only slightly injured, indicating that in some cases they may obtain additional food by transfer to another floret. Feeding and injury in these cases were limited to the apex of the pod.

Often more than one larva begins development in a floret. In most cases only one individual survives longer than 2 or 3 days. Under conditions where two develop together, one will usually be dwarfed. In only one case were two mature larvae found in a single floret.

The average time required for the larvae to reach maturity was observed to be 13 days (Table 1). The average time for June and August was 14.3 and 11.7 days, respectively.

How long a larva remains in the floret after reaching maturity is somewhat variable. During damp or rainy weather there is a tendency for the larvae to leave the florets shortly after reaching maturity. During dry weather some larvae remain in the florets for a week or more.

Table 1.—Days required for the development of the larval stage.[1]

Date			Days Required for Development[2]
Eggs Were Laid	Florets Were Examined	Number Matured	
June 2	June 14	0	—
June 2	June 16	2	11.5
June 2	June 17	1	12.5
June 2	June 18	3	13.5
June 2	June 19	7	14.5
June 2	June 20	8	15.5
June 2	June 21	10	16.5
Aug. 7	Aug. 18	0	—
Aug. 7	Aug. 19	2	9.9
Aug. 7	Aug. 20	4	10.9
Aug. 7	Aug. 21	7	11.9
Aug. 7	Aug. 22	9	12.9
Aug. 7	Aug. 23	10	13.9
Average			13.0

[1] Based on 10 individuals.
[2] Two and one-half days were subtracted for the egg stage in June, and 2.1 days were subtracted in August.

However, all larvae were observed to have left the florets before the portion of the head in which they were located began to dry.

Cocoon spinning.—Upon leaving the floret, the larva drops to the ground, crawls under debris or under the top, loose soil, and spins a silken cocoon. Laboratory observations indicate that the cocoon is begun within 24 hours after the larva leaves the floret, and is completed within 12 to 24 hours. Under laboratory conditions a few larvae pupate without spinning cocoons. This has not been observed in the field.

The process of cocoon spinning as observed when mature larvae were placed on damp, tightly-packed cotton, is as follows: The larvae burrow into the cotton until at least a few strands cover their bodies. The silk for the cocoon is secreted through an opening on the anterior portion of the head. While spinning the cocoon the larva keeps the anterior portion of the body in constant motion, apparently attaching the silk at a point, drawing it out, and then attaching it at another point. This procedure is repeated until a section of the cocoon is finished; then the larva changes position and works on another section. It often reverses its position several times before the cocoon is completed. When the lighting was favorable the single strands of silk could be seen as they were emitted. Only rarely will a larva removed from its cocoon spin a second cocoon. In laboratory tests such larvae usually had their prepupal period extended, formed abnormal pupae, or failed to pupate.

Pupal period.—With the exception of those which go into dormancy, most larvae pupate within 2 to 5 days after they spin their cocoons. The length of time from cocoon spinning to emergence of the adult ranged from 11 to 18 days, with an average of 13.9 days (Table 2).

Table 2.—Length of time from cocoon-spinning to emergence.[1]

Date Larvae Spun Cocoons	Date of Emergence	Males	Females	Days from Cocoon Spinning to Emergence
Aug. 15	Aug. 27	0	3	12
Aug. 15	Aug. 28	0	3	13
Aug. 15	Aug. 29–30	1	1	15–16
Aug. 15	Aug. 31	0	2	17
Aug. 16	Aug. 27	0	4	11
Aug. 16	Aug. 28	1	10	12
Aug. 16	Aug. 29	0	1	13
Aug. 16	Aug. 31	2	13	15
Aug. 16	Sept. 1	1	1	16
Aug. 16	Sept. 2	0	2	17
Aug. 16	Sept. 3	0	1	18
Average				13.9

[1] All larvae left florets on August 14.

Table 3.—Summary of length of stages in days.

	Number Observed	Minimum	Maximum	Average
Egg	79	1.91	2.58	2.27
Larval	63	9.90	16.50	13.0
Prepupal and pupal	46	11.0	18.0	13.90
Total		22.81	37.08	29.17

Data were collected at various times throughout the season on larvae pupating without forming cocoons. The average length of time spent in the pupal stage as recorded in 8 observations was 10.1 days, with a range of 8 to 12 days.

When the pupa has completed its development it forces its way out through the end of the cocoon. If the cocoon is exposed, the pupa usually forces out only its head and thorax, and when the adult emerges, the empty pupal case is left partially within the cocoon. However, when the cocoon is buried, the pupa frees itself and makes its way to the surface before the adult emerges. The pupa crawls by alternately contracting its abdomen and thrusting forward.

Summary of stages.—Observations on the duration of the various developmental stages of the Ladino clover seed midge are summarized in table 3. The average period from egg to adult was 29.2 days, with a minimum of 22.8 and a maximum of 37.1.

Sexual development.—Laboratory observations indicate that the adults of the Ladino clover seed midge reach sexual maturity within a few hours after emerging. In several cases mating was observed in emergence tubes from which the adults were removed every 24 hours. In one case males and females, which had emerged the previous night, were placed in a bell jar containing a potted clover plant. By afternoon mating and limited oviposition had taken place.

Longevity of adults.—Under laboratory conditions the male of the Ladino clover seed midge lived from 1 to 3 days, while the female lived from 2 to 4 days. The adult does not behave normally in confinement, however, being very nervous and usually seeking escape. Therefore the observed longevity is probably shorter

than would occur in normal surroundings.

Number of generations.—There seem to be no clearly defined generations of the Ladino clover seed midge. The fluctuations in population during the season would seem to be due to weather conditions and activity of parasites and predators rather than to different broods. However, field observations indicate that at least one generation develops in the early growth of clover which is usually cut for forage; at least two generations occur during the development of the clover seed crop; and in most fields at least a partial generation develops in the clover occurring after the seed crop is harvested.

Hibernation.—The Ladino clover seed midge hibernates as the mature larva which is ordinarily enclosed in its cocoon. Larvae maturing late in the fall may overwinter without spinning cocoons. These larvae either seek protected places under debris or remain in the florets in which they developed. Apparently the larva must be subjected to a certain period of cold weather before its dormancy is broken. Dormant larvae exposed to room temperatures slowly shriveled, and died within 2 or 3 months.

NATURE OF INJURY.—The feeding injury of the Ladino clover seed midge larva reduces the seed yield. Only the pods and the enclosed seeds are affected, while the flower parts and other portions of the plant develop normally. This midge, therefore, is only of economic importance when seed is to be produced. The feeding of the larva of this insect causes a shrinking and collapsing of the pod and its enclosed seeds. Damaged pods are usually reduced to about one-half the width and two-thirds the length of a normal pod. Occasionally one or two seeds develop farther than the rest, giving the pod an irregular appearance. An injured seed is about one-half the size of a normal seed. It is typically flattened, pale in color, and translucent. The seed coat is thin and brittle, and the inside of the seed is hollow. Injured seeds exposed to field conditions through periods of rain usually become darkened with molds. A mature floret containing an injured pod has a flattened appearance. A mature head of clover containing a large percentage of damaged florets, however, is very difficult to distinguish from an undamaged head.

PARASITES AND PREDATORS.—Two species of parasites were found to attack the Ladino clover seed midge. One of these, a metalic-blue chalcid, was identified as *Tetrastichus* sp., near *marcovitchi* (Cwfd.), and quite probably undescribed.[3] The other parasite, belonging to the family Ceraphronidae, was identified as *Ceraphron* n. sp., near *pacifica* (Whitt.).[3]

The chalcid parasite was present in the field throughout the active period of the midge, but was most abundant during August and September. The larva passes the winter in the body of the midge maggot, completes its development in the spring, and emerges at about the same time as the adult midge. The egg of the parasite is apparently inserted into the body of the partially grown maggot. The first external evidence of the presence of the parasite appears about the time the maggot would normally mature. At this time the maggot becomes noticeably flaccid and weakened to such an extent that it may not leave the floret. Very shortly the maggot dies and the parasite completes its development by consuming the internal portion of the maggot. The integument of the maggot then turns light brown to nearly black in color and becomes hard, forming a protective case for the parasite. The pupal stage lasts from 1 to 2 weeks. Limited observations indicate that the life history of the ceraphronid parasite is very similar to that of the chalcid parasite.

In examinations made during August, 40 out of 100 midge larvae removed from florets of Ladino clover were parasitized. At the same time only five parasitized larvae were found in a group of 100 which had left the florets. This indicates the inability of most parasitized larvae to leave the florets. Eighty-one parasites were reared from 625 overwintering larvae collected in an alsike clover field.

Crab spiders, which commonly conceal themselves among the unopened florets, were often observed to prey upon adult midges visiting the clover blossoms.

SUMMARY.—A new pest, the Ladino clover seed midge, was found in the Evans Creek area of Southern Oregon in July, 1950. A study of the life history and habits of this insect was begun at that time and continued through 1952.

[3] Determined by B. D. Burks, and C. F. W. Muesebeck, respectively, Entomology Research Branch, Agr. Res. Serv., U.S.D.A.

In all areas investigated, Ladino clover was found to be the chief host of this midge. Alsike clover growing in the vicinity of Ladino clover was found to be infested. No stages of this insect were definitely identified from any other clovers examined. This insect is present and of economic importance in the seed producing areas in Oregon and Washington.

The Ladino clover seed midge passes the winter as a mature larva in a silken cocoon. Spring emergence begins about the middle of May at the Southern Oregon Experiment Station and continues through early June. The midge was generally active in infested fields during the summer and fall of 1951 and 1952. Populations of this midge were highest during late August and early September.

The eggs are deposited in the open florets of the clover head. Upon hatching the young larva moves to the pod where it feeds by sucking juices. Shortly after reaching maturity, the larva drops to the ground and forms a silken cocoon within which it pupates. The average time required to develop from the egg to the adult was 29.2 days. The period of development in days for the different stages averaged 2.3 for the egg, 13 for the larva, and 13.9 for the prepupa and pupa. Field observations indicate that there are 3 to 4 generations a year.

Sexual maturity is apparently reached within a few hours after emergence. Under laboratory conditions the adult lives from 2 to 4 days.

Two parasitic wasps, *Tetrastichus* sp. and *Ceraphron* n. sp., were found to be internal parasites of the midge maggot.

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Joint Use of Parasites and Insecticides for Control of the Oriental Fruit Moth

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It has been shown that mass liberations of parasites against the oriental fruit moth, *Grapholitha molesta* (Busck), on peach increased parasitization of larvae in twigs and reduced ripe-fruit injury in moderately late-maturing varieties such as Elberta (Brunson 1940, Brunson & Allen 1944). During the 10-year period 1938 to 1947 mass liberation of parasites, mostly *Macrocentrus ancylivorus* Roh., against first- and second-brood larvae in orchards near Moorestown, N. J., reduced ripe-fruit injury 80 per cent under the best conditions and slightly less than 50 per cent on an average (Allen 1948).

Before DDT was available, mass liberation of parasites was the only effective control measure against the oriental fruit moth on peach. Since DDT became available to growers, the use of this and other insecticides in preharvest applications has become almost the only method of control, and the value of natural control agents has been largely disregarded. In view of the possibility that wide and exclusive use of insecticides might reduce the high natural population of oriental fruit moth parasites, experiments were conducted near Moorestown, N. J., in 1947 and 1949 to 1952, in which parasites and insecticides were used jointly.

METHODS.—The effectiveness of parasite liberations and different preharvest sprays in reducing ripe-fruit injury was tested in blocks of Summercrest and Elberta peaches. These are the latest commonly grown commercial varieties in southern New Jersey and are likely to be moderately to heavily injured. They ripen during the last 2 weeks in August.

Macrocentrus ancylivorus, which was reared on the potato tuberworm, *Gnorimoschema operculella* (Zell.), was used in all the liberations. During the period when oriental fruit moth larvae were abundant in twigs, adult parasites were released at

[1] Assisted by E. L. Plasket.

4- to 5-day intervals. There were usually five liberations per brood, and the number of parasites in each liberation was proportional to the rise and fall of the larval population. For example, 10, 20, 35, 25, and 10 per cent of the total parasites to be used per brood in an orchard were liberated consecutively, the greatest percentage when larvae had been found to be most abundant (Allen 1948). In the section where these experiments were conducted, the first brood is at a peak about May 31, and the second brood about July 4.

Since parasite migration makes it impossible to determine, within the limits of single orchards, any significant difference between the effect exerted in a plot where the parasites were liberated and any check plot receiving no parasites, it is necessary to measure the effect of parasites in terms of differences between separate orchards. Parasites were released in two to six orchards each year. Each year fruit injury in the orchards receiving parasites was compared with that in at least six orchards in which no parasites or insecticides were used to reduce oriental fruit moth injury. Since the effect of parasite liberations is not always discernible when single orchards are compared, analysis of the effect of liberations is based on groups of two or more orchards.

Two or more preharvest sprays were tested on one-tree plots in each parasite-treated orchard. One series received two applications and all others, except the no-spray checks, received one application. The plots were randomized and replicated 7 to 10 times. Each plot was separated from other plots by one unsprayed tree. Sprays were applied with a hand gun at a pump pressure of about 400 pounds per square inch. The effect of the sprays was measured by comparing the injury at harvest in the different series of spray plots and the check plots. Since the total area of the sprayed plots comprised only a small part of each orchard, the unsprayed portion provided an adequate basis for measuring the effect of parasite liberations.

The insecticides used each year and the quantities per 100 gallons of water are given below. Wettable-powder formulations of DDT, parathion, and EPN were used and an emulsifiable concentrate of Metacide.

DDT	
Active ingredient, 0.96 pound	1947
50%, 2 pounds	1949, 1950
75%, 1.5	1951
Parathion	
25%, 1 pound	1949
15%, 2	1950, 1951
15%, 1.5	1952
EPN 25%, 1.5 pounds	1951, 1952
Metacide 50%, 0.5 pint	1952

Fruit injury was estimated by dissecting the fruits in samples of 200 to 560 taken when ripe and ready to harvest. An equal number of fruits were taken at random from each plot. In the orchards in which no oriental fruit moth control measures were used, one or two fruits were taken at random from each tree passed as the block of trees was traversed diagonally in many directions.

The orchard area included in these experiments contained 3,443 trees in 1947, 4,868 in 1949, 8,535 in 1950, 3,496 in 1951, and 2,900 in 1952—a total of 23,242 trees, about 250 acres.

EXPERIMENTS IN 1947 AND 1949.—In 1947 three orchards received parasites at the rate of three females per tree during the second brood of the fruit moth. In addition, bait traps were used in each third tree in each third row from June 9 to August 14, during which time they caught an average of 13 moths per tree. In each of these orchards three series of plots were sprayed and a similar series of unsprayed plots served as a check. When one application was used it was made between July 22 and 24, and when two were used they were made between July 9 and 14 and again between July 22 and 24. Fruit samples were taken between August 19 and 27.

The results of the first year's work, presented in table 1, indicate that when parasites, bait traps, and preharvest sprays were used there was an average reduction of 73 per cent in the fruit moth injury, a substantial portion of which was due to parasites and baits. There were no means of segregating the portion due to baits, but in two previous years in which baits were used alone as a means of control no significant reduction of injury was obtained. It appears from this table that no reduction of injury was obtained from the sprays, but in associated experiments there was a 25 per cent

Table 1.—**Effect of joint use of parasites, bait traps, and DDT on per cent of peaches showing oriental fruit moth injury at harvest, 1947.**

Orchards in Which Parasites and Bait Traps Were Used With and Without Sprays			
Orchard No.	Plots Receiving One Application	Plots Receiving Two Applications	Plots Receiving No Spray
1	12.8	15.5	13.3
2	12.7	11.4	19.1
3	6.3	3.7	8.2
Average	10.6	10.2	13.5

Orchards receiving no oriental fruit moth control, 56.9, 30.7, 63.0, 44.1, 28.0, 10.2; average 38.8.

reduction in injury when the same sprays were used once in orchards not treated with parasites and bait traps, and a 34 per cent reduction when they were used twice. When DDT was first used, it was considered desirable to avoid appreciable residues at harvest; so final applications were made not less than a month before harvest. Our present knowledge of timing preharvest sprays suggests that in 1947 the final application was made 1 week too early for the best results.

In 1949 the use of bait traps was discontinued. There were joint liberations and spray treatments in three orchards. Three spray treatments were applied to plots in each orchard. The plots were sprayed between July 26 and 29, and when two applications were made the first was between July 13 and 16. These plots were checked against a no-spray series of plots, and a series of orchards receiving no fruit-moth control, as in 1947. The three treatments included parathion followed by DDT, a single parathion application, and a single DDT application. The results are as shown in table 2.

Only one of the seven check orchards had more than 25 per cent of the fruit injured; yet two of the three orchards in which parasites were liberated had more. Thus, there was no observed reduction of injury due to parasites, and the average of 10.2 per cent injury after use of both parasites and sprays was not significantly lower than the average in the check orchards.

EXPERIMENTS IN 1950, 1951, AND 1952.—The experiments were repeated in 1950, 1951, and 1952. About the same methods were used as in 1947 and 1949. Parasites were liberated in six orchards in 1950, three in 1951, and two in 1952. In 1950 three females per tree were released against the first brood, but when the second brood was present the supply of parasites was inadequate; hence only 1.1 females per tree were released. In 1951 and 1952 three female parasites per tree were released against each of the first two broods.

In 1950 parathion was used in one and two applications and DDT in one application. The single applications were made between July 31 and August 2, and when there were two applications the first was made on July 11 and 12. During 1951 parathion was used in one and two applications, and DDT and EPN each in one application. The single application was made July 30, and when there were two applications the first was made on July 9 and 10. In 1952 Metacide was used instead of DDT. Parathion was tried in both one and two applications, but each of the other insecticides was used in one application. The single application was made on July 31. When two parathion sprays were used, the first was applied on July 11. Fruit injury was determined from samples taken August 18 to 23 in 1950, August 16 to 23 in 1951, and August 17 to 21 in 1952.

The results obtained during these 3 years are shown in tables 3, 4, and 5. The average injury in orchards receiving no oriental fruit moth control was remarkably uniform, ranging from about 23 to 25 per cent. Each year fruit injury was substantially reduced by parasite liberations, and further reduced by preharvest sprays. The combined effect reduced in-

Table 2.—**Effect of joint use of parasites and insecticides on per cent of peaches showing oriental fruit moth injury at harvest, 1949.**

Orchards in Which Parasites and Sprays Were Used				
Orchard No.	Plots Receiving One Application of Parathion	Plots Receiving One Application of DDT	Plots Receiving an Application of Parathion Followed by an Application of DDT	Plots Receiving No Spray
1	6.0	5.5	4.0	6.0
2	4.0	17.5	9.0	26.5
3	10.1	21.7	14.0	27.5
Average	6.7	14.9	9.0	20.0

Orchards receiving no oriental fruit moth control, 10.3, 14.3, 28.3, 5.2, 17.5, 3.5, 4.3; average 11.9.

Table 3.—Effect of joint use of parasites and insecticides on per cent of peaches showing oriental fruit moth injury at harvest, 1950

	Orchards in Which Parasites and Sprays Were Used				
Orchard No.	Plots Receiving One Application of Parathion	Plots Receiving One Application of DDT	Plots Receiving Two Applications of Parathion	Plots Receiving No Spray	L.S.D. at 5 Per Cent Level
1	4.5	2.5	1.0	11.0	5.4
2	1.5	3.3	1.0	10.0	4.7
3	7.5	4.0	1.5	6.5	6.4
4	3.0	3.0	2.0	10.0	4.2
5	1.5	—	4.0	9.5	—
6	5.5	3.5	4.5	6.5	5.4
Average	3.9	3.3	2.3	8.9	

Orchards receiving no oriental fruit moth control, 27.5, 17.0, 45.5, 5.0, 34.5, 12.5; average 23.7.

jury of the fruit at harvest to 1.2 to 3.9 per cent.

Experiments With Insecticides Only.—During the 5 years in which parasites and insecticides were used jointly there were comparable experiments in which only insecticides were employed. The results of these experiments are presented in table 6. The results for the plots receiving both DDT and parathion in 1949 are not included, as it was found that the DDT used that year was inferior in quality. The results with Metacide are also omitted, since only three tests were made and the results closely parallel those obtained with parathion and EPN.

The reductions in injury obtained from all insecticides used in a one-spray schedule and from parathion in a two-spray schedule were significant at the 1 per cent level. The average reduction ranged from 44 to 83 per cent. In the three orchards in which DDT was used in a two-spray schedule, the reduction was not statistically significant.

In three tests (1951) one spray of DDT averaged 77.0 per cent reduction of injury and one spray of EPN 85.0 per cent. In 11 tests (1949, 1950, and 1951) one spray of DDT averaged 50.2 per cent reduction of injury and one spray of parathion averaged 49.4 per cent. In five tests (1951 and 1952) one spray of parathion averaged 64.0 per cent reduction of injury and one spray of EPN 82.6 per cent. In 11 tests (1950, 1951, and 1952) one spray of parathion averaged 56.2 per cent reduction of injury and two sprays of parathion 74.9 per cent. Although some of the differences between these group averages appear substantial, particularly the difference between one and two parathion sprays, none were significant at the 5 per cent level.

Discussion.—During the 5 years these experiments were conducted, the reduc-

Table 4.—Effect of joint use of parasites and insecticides on per cent of peaches showing oriental fruit moth injury at harvest, 1951.

	Orchards in Which Parasites and Sprays Were Used					
Orchard No.	Plots Receiving One Application of Parathion	Plots Receiving One Application of DDT	Plots Receiving One Application of EPN	Plots Receiving Two Applications of Parathion	Plots Receiving No Spray	L.S.D. at 5 Per Cent Level
1	2.5	1.5	1.0	1.5	13.0	4.0
2	5.0	3.0	1.5	1.0	7.5	4.7
3	1.0	0.5	0.5	1.0	3.0	3.3
Average	2.8	1.7	1.0	1.2	7.8	

Orchards receiving no oriental fruit moth control, 4.0, 70.5, 31.5, 11.3, 12.5, 8.5; average 23.1.

Table 5.—**Effect of joint use of parasites and insecticides on per cent of peaches showing oriental fruit moth injury at harvest, 1952.**

	Orchards in Which Parasites and Sprays Were Used					
Orchard No.	Plots Receiving One Application of Parathion	Plots Receiving One Application of EPN	Plots Receiving One Application of Metacide	Plots Receiving Two Applications of Parathion	Plots Receiving No Spray	L.S.D. at 5 Per Cent Level
1	6.5	4.0	5.0	3.0	13.0	5.2
2	0.5	0.5	0.5	1.0	4.5	2.5
Average	3.5	2.3	2.8	2.0	8.8	

Orchards receiving no oriental fruit moth control, 22.0, 30.0, 21.0, 37.8, 16.5, 18.8; average 24.4.

tion of injury from the use of parasites followed the usual pattern (Brunson & Allen 1944). Despite the fact that no reduction of ripe-fruit injury was evident in two of the three orchards in 1949, the 5-year average was 11.8 per cent of injured fruits in orchards receiving parasites compared with 24.4 per cent in orchards where no fruit moth control was used. The difference is significant at the 5 per cent level. The reduction due to the parasite liberations averaged 52 per cent for the 5-year period and 64 per cent for the last 3 years. In 15 of 17 orchards in which parasites were used, the injury at harvest was substantially less than the average for the orchards that received no fruit moth control.

The degree of control of oriental fruit moth injury to ripe fruits obtained by the joint use of parasites and one spray application is compared below with the control obtained by the use of two spray applications without the parasites. Presumably

Table 6.—**Reduction in oriental fruit moth injury to ripe fruits resulting from sprays, 1947–1952.**

Year and Orchard No.	Per Cent of Fruits Injured in Check Plots	Per Cent Reduction of Injury				
		In 1-Spray Plots			In 2-Spray Plots	
		DDT	Parathion	EPN	DDT	Parathion
1947						
1	13.3	4	—	—	−17	—
2	19.1	34	—	—	40	—
3	8.2	23	—	—	55	—
1949						
1	6.0	8	0	—	—	—
2	26.5	34	85	—	—	—
3	27.5	21	63	—	—	—
1950						
1	11.0	77	59	—	—	91
2	10.0	67	85	—	—	90
3	6.5	38	−15	—	—	77
4	10.0	30	70	—	—	80
5	9.5	—	84	—	—	58
6	6.5	46	15	—	—	31
1951						
1	13.0	88	81	92	—	88
2	7.5	60	33	80	—	87
3	3.0	83	67	83	—	67
1952						
1	13.0	—	50	69	—	77
2	4.5	—	89	89	—	78
Average	—	43.8	54.7	82.6	26.0	74.9

the costs of using these two methods were approximately equal.

	Per Cent Control				
	1947	*1949*	*1950*	*1951*	*1952*
Parasites and insecticides	73	44	85	92	89
Insecticides only	34	86	80	82	93

During the last 3 years the control obtained by the joint use of parasites and insecticides was as good as from the use of insecticides only. Parasites and insecticides used jointly in a section having moderately heavy injury—i.e., 23 to 25 per cent—reduced it to 2.6 per cent.

From the spray tests it was concluded that each of the insecticides caused a substantial reduction of oriental fruit moth injury, when used as a preharvest spray where parasite liberations had previously reduced the infestation to a low level. No one insecticide was superior to the others, and it could not be shown conclusively that two applications in such orchards provided any better control than one application.

SUMMARY.—Experiments in the joint use of parasites and insecticides for control of the oriental fruit moth, *Grapholitha molesta* (Busck), on ripe peaches were conducted for 5 years in southern New Jersey. Mass liberations of *Macrocentrus ancylivorus* Roh. were made against the first two broods, at rates not exceeding six females per tree. The parasite liberations were followed by one or two preharvest spray applications of DDT, parathion, EPN, and Metacide at the customary concentrations.

It was found that the parasite liberations reduced fruit injury by 52 per cent for the 5 years of the experiments, and 64 per cent for the last 3 years. Each of the insecticides tested reduced the injury further by 44 to 83 per cent. Despite the wide differences in degree of control, none of the differences between insecticides, or between one and two preharvest applications were found to be significant. The joint use of parasites and one insecticide application over the 5 years of the experiment gave a reduction of injury about equal to that obtained when two preharvest applications of insecticide were used without parasites.

It is concluded that, under conditions such as occurred during the period of this experiment, satisfactory control of the oriental fruit moth in ripe Summercrest and Elberta peaches can be obtained from mass liberations of parasites and one preharvest application of a suitable insecticide.

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BOOK REVIEW

ATLAS OF THE SCALE INSECTS OF NORTH AMERICA, Vol. VI. By Gordon Floyd Ferris, pages vii, 279-506, Figures 109–193. Stanford University Press, 1953. Price $7.50.

This volume completes the study of the family Pseudococcidae which began with volume V, and includes five new genera; 98 species, 22 of them new; and two new names. The two volumes are so closely associated, it is desirable to discuss them as a unit. The pagination is continuous, the figures are numbered consecutively; and volume VI has the index for both volumes and the keys to the genera and species of both volumes.

The two volumes treat 39 genera, 15 of them new; 201 species, 41 of them new; new names are provided for two species and have 193 full page illustrations. It is the first effort that has been made to treat the mealybugs of North America as a whole. Until these two volumes appeared the literature pertaining to these insects consisted principally of widely scattered short papers dealing with descriptions of one to several species. The generic assignments in many instances were questionable, which resulted in the assignment of forms to genera to which they were unrelated. This situation resulted in the several new genera that were proposed in volumes V and VI of the atlas.

Future workers in this group of scale insects will miss the usual citations of literature of the original descriptions and in the synonymy of the various species, and will wish they could have been included. However, these citations require space and increase the costs of publication. Costs can be the factor that determines whether a paper is printed, or remains in the filing cabinet as a manuscript.

H. S. MCCONNELL

Proteinaceous Bait for the Oriental Fruit Fly

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The oriental fruit fly, *Dacus dorsalis* Hendel, developed to serious pest proportions shortly after it was discovered in Hawaii in 1946. There was soon evident a need for lures that could be used in traps to detect at the earliest possible moment incipient infestations that might occur at any time on the mainland. Such lures might also be useful in direct control procedures when used in traps or to attract the flies to poisoned bait sprays or to poisoned feeding stations. A less urgent but nonetheless important need was a suitable lure and trap for use in biological and ecological studies to measure population densities, trends, and variations occurring in response to changes in environmental factors.

During the period of the oriental fruit fly's remarkably rapid increase and spread, oil of citronella, attractive to the males, became the standard attractant employed by Hawaiian entomologists in their scouting activities and population studies. Later fermenting lures,[2] attractive to both sexes, came into extensive use for the same purposes. Methyl eugenol was found to be useful in 1949, after its phenomenal attractiveness to male oriental fruit flies was demonstrated by Steiner (1952a). There remained an urgent need for a more powerful lure for the female oriental fruit fly, and materials highly attractive to the melon fly, *Dacus cucurbitae* Coq., and the Mediterranean fruit fly *Ceratitis capitata* (Wied.). The proteinaceous lure described herein is the best one developed thus far for female oriental fruit flies and both sexes of the melon fly.

METHODS FOR TESTING BAITS.—In field tests with potential oriental fruit fly baits, the materials were compared in glass invaginated traps suspended in blocks of four from rotating cross arms. The rotation of the cross arms, which minimized positional differences, was activated by the pressure of the wind on specially constructed cups. Each test consisted of 12 replications of these blocks of traps separated from each other by at least 100 feet, and usually by much greater distances. Four baits, one of which was the standard for comparison, were tested on each trap suspension.

Olfactometer tests were carried out in a cage 9 by 9 by 8 feet, well stocked with a large population of oriental fruit flies, and in later studies with Mediterranean fruit flies and melon flies as well. The test materials were contained in small glass invaginated traps suspended from a slowly rotating, motor-driven wheel mounted horizontally on a bearing through the roof of the cage. Usually three replications of four baits were tested at the same time.

Because of differences in time of exposure and location, it was necessary to adopt a reproducible bait as a standard for comparison in all tests. The van Zwaluenburg fermenting bait[2] used for this purpose consisted of 80 grams of raw sugar, 13 cc. of white vinegar, and one-fourth cake of yeast per liter of water. The large quantity of yeast, a highly standardized product that is always available in fresh form, was used to insure suppression of the growth of wild microorganisms.

The diet for the flies in the large olfactometer cage—usually from 25,000 to 100,000—consisted of raw sugar, yeast hydrolysate, canned papaya and guava juices, and sections of mature tomato and guava fruits. The inclusion of yeast hydrolysate had to be limited to 2 days per week in order to obtain responses of the oriental fruit fly to fermenting and proteinaceous baits comparable with those obtained under field conditions.

In both the field and olfactometer tests, counts were made of both sexes, and the results were subjected to statistical analysis. Only the materials that showed promise in the olfactometer tests, which could

[1] L. F. Steiner and C. C. Roan, of the Entomology Research Branch, and K. S. Hagen and G. S. Finney, of the California Agricultural Experiment Station, contributed advice and assistance of much value in these studies. Miss Shizuko Maeda, of the Branch, acted as consultant on microbiological phases, and isolated and purified the bacterial strains that were used. O. A. Bushnell, of the University of Hawaii, contributed advice on the bacteriological phases, and worked on the identification of bacterium 14. Miss Doris Hayashi of the Branch, carried out olfactometer tests, counted field collections of flies, and made statistical analyses of the data.

[2] One formula was developed by R. H. van Zwaluenburg, Hawaiian Sugar Planters Association Experiment Station. A bait developed at the Mexico City laboratory of the Entomology Research Branch was also used.

be completed in a single day, were used in the more time-consuming field tests. The olfactometer cage was also used to study microbiological action in baits at different time intervals and to determine the materials most readily attacked by microorganisms.

AMMONIACAL BAITS.—Ammonia has been used as a fruit fly attractant for more than 20 years. The Queensland fruit fly, *Chaetodacus tryoni* (Froggatt), the Jarvis fruit fly, *Dacus jarvisi* (Tryon), the small black fruit fly, *D. niger* Tryon, the solanum fruit fly, *D. cacuminatus* (Hering), the boatman fruit fly, *Rioxa pornia* (Walker), and the Mediterranean fruit fly are all attracted by a bait consisting of imitation extract of vanilla and ammonia (Jarvis 1931). The Queensland fruit fly is also lured by ammonia evolving from ammonium carbonate (Perkins & Hines 1934). The olive fruit fly, *D. oleae* (Gmel.), is attracted by various ammonium salts, combinations of these salts with molasses, by a proprietary ammonium soap known as Clensel (Bua 1933, 1938), and by ammonium phosphate (Borhorquez 1940). The Mediterranean fruit fly also responds to Clensel (Newman & O'Connor 1931). The apple maggot, *Rhagoletis pomonella* (Walsh), is attracted to a mixture of ammonia and ammonium sulfate (Hodson 1943).

Powdered egg albumin, a peptone preparation, and dried yeast powder with alkali are apple maggot baits (Dean 1941, Benjamin & Hodson 1942). The Walnut husk fly, *Rhagoletis juglandis* Cress, is attracted by casein in combination with sodium hydroxide and by glycine in water or with sodium hydroxide (Boyce & Bartlett 1941). In Mexico *Anastrepha striata* Schiner has been found to be attracted by various proteinaceous materials mixed with sodium hydroxide, including casein, gelatin, filter-press mud, baker's yeast, cowhide with hair attached, cow blood, white of egg, and wheat shorts (McPhail 1939). Ammonia given off during decomposition was believed to be responsible for the attractiveness of these proteinaceous baits. Traps containing ammonium carbonate have been found very attractive to the cherry fruit fly, *Rhagoletis cingulata* (Loew), in Washington (Frick 1952).

In replicated field tests with baits exposed in suspended rotating traps the Jarvis ammoniacal bait (0.67 per cent of ammonium hydroxide plus 0.5 per cent of artificial vanilla extract) and the standard fermenting bait, the latter augmented by ammonium carbonate in an open vial suspended from the stopper of the invaginated glass trap, were about equally attractive to the oriental fruit fly, but only half as attractive as the standard bait. A bait consisting of 0.33 per cent of ammonium hydroxide plus 3 per cent of ammonium carbonate in water was only one-sixth as effective as the standard, all differences being highly significant. Ammonia alone was slightly attractive. However, when combined with the fermenting bait it was either repellent or it obscured attractants produced by fermentation processes.

STUDIES WITH PROTEIN HYDROLYSATES AND B VITAMINS.—In nutritional studies with the oriental fruit fly, Hagen & Finney (1950) found that yeast hydrolysate contains dietary elements essential for the development of this fly. Steiner (1952b) subsequently developed an effective bait-spray formula containing yeast hydrolysate after he observed that these flies were strongly attracted to deposits of this material when it was sprayed on guava foliage.

A proprietary yeast hydrolysate[3] was tested in the field at concentrations of 0.2, 1.0, and 5.0 per cent to evaluate more precisely its attractiveness to the oriental fruit fly. In one test it was dissolved in water; in another it was added to the standard bait. In the combination bait there was a pronounced increase in the rate of fermentation during the first week, which was accompanied by a decrease in catch, probably as a result of the rapid consumption of the protein hydrolysate (as a source of nitrogen) by the yeast. Increases in the catch obtained with 1 per cent of yeast hydrolysate in the standard bait during the second week indicated that additional attractants had been formed. The 0.2 per cent yeast hydrolysate concentration in water was more than twice as effective as the standard bait during the 2-week test period, but the 5.0 per cent concentration in water caught only one-fifth as many flies as the standard bait. In the traps containing yeast hydrolysate in water there was con-

[3] Manufactured by Marvin R. Thompson, Inc., Stamford Conn.

siderable evidence of development of microflora together with strongly putrefactive odors.

In the next series of tests 6-inch cotton dental rolls were soaked in 2, 10, and 50 per cent solutions of yeast hydrolysate and then suspended from the stoppers of traps containing standard bait. Catches during a 2-weeks' period were 1.9, 2.0, and 2.8 times, respectively, as high as those obtained with the standard bait. When yeast hydrolysate solutions in water at concentrations of 0.2, 1.0, and 5.0 per cent were protected by antibiotics (10 p.p.m. of tyrothrycin and 100 p.p.m. of dihydrostreptomycin) to eliminate putrefaction and inhibit mold growth, the catches were 3.3, 5.0, and 2.9 times as great as those obtained with the standard bait in order of increasing concentration. The yeast hydrolysate-water bait appeared to be considerably improved by the protection provided by the antibiotics, and the 1.0 per cent concentration gave the best results.

Since the yeast hydrolysate used in these tests consisted principally of amino acids and B vitamins, it was possible that these components, individually or in combination, may have been responsible for its attractiveness. A vitamin-B preparation called *Lederplex*[4] was selected for trial in the next experiment because its vitamin balance is in fair agreement with that of the yeast hydrolysate. It was removed from the gelatin capsules and dissolved in the standard lure, or in water, and no effort was made to protect it from decomposition. A slight odor of putrefaction was noted in the traps at the end of the first week. As the concentrations selected for the tests were calculated to match the concentrations of yeast hydolysate on the basis of riboflavin content, a fairly good approximation of the yeast hydrolysate-vitamin balance was given, except for thiamine, which was at a considerably lower level in the vitamin-B preparation than in the yeast hydrolysate. When added to standard bait at concentrations of 0.25, 2.5, and 12.5 capsules per liter, *Lederplex* showed no significant gains over the standard bait alone during a 2-week period. *Lederplex* in water at the same concentrations gave respective catches 0.2, 3.8, and 7.2 times those of the standard bait, indicating that it was considerably more attractive to the oriental fruit fly than yeast hydrolysate.

Pure B vitamins dissolved in water were tested separately in the field at approximately the same concentrations at which they occurred in the best *Lederplex* concentration. The vitamins and concentrations (parts per million) used were as follows: thiamin hydrochloride and riboflavin each 25, choline chloride 250, calcium pantothenate 37.5, inositol and niacinamide each 125, pyridoxine hydrochloride, folic acid, and biotin each 2.5, and *p*-aminobenzoic acid 500.

Only choline chloride showed significant attraction to the oriental fruit fly, but the catch with this material was only 93 per cent of that with the standard bait. This was not sufficient to account for the attractiveness of the *Lederplex* solutions or that of the yeast hydrolysate. A test with all of the pure B vitamins in combination showed no significant attraction in a test in which *Lederplex* caught 7.1 times as many flies as the standard. From these tests it was concluded that the B vitamins were not responsible for the attraction of *Lederplex*, or the yeast hydrolysate, and that the source of attractants was probably proteinaceous compounds of the liver extract in this material. Since cage olfactometer tests also failed to show any attraction by choline chloride, it was believed that the attraction of the choline in this case was due to products of bacterial action.

In a field comparison of *Lederplex* and soy, casein, and lactalbumin hydrolysates, all of which were protected against putrefaction by the antibiotics indicated previously, the soy hydrolysate was more attractive than *Lederplex*, and the casein and lactalbumin hydrolysates were less attractive. In tests with soy, casein, and lactalbumin hydrolysates protected by antibiotics and enriched by a complete vitamin-B mixture (except for B-12), the soy hydrolysate plus vitamin-B complex was more attractive than soy hydrolysate alone. In the traps containing casein and lactalbumin hydrolysates enriched with the vitamin-B complex, there were so many blow flies after 2 days that the traps could no longer catch any fruit flies.

PRODUCTION OF ATTRACTANTS BY BAC-

[4] Produced by the Lederle Laboratories Division, American Cyanamid Company, New York City.

TERIA.—The antibiotics used in the above tests with protein hydrolysates prevented putrefaction, but there was considerable evidence of microbiological changes of a nonputrefactive type. When *Zephiran* (a mixture of high-molecular alkyl benzyl dimethyl ammonium chlorides) was added to baits of *Lederplex* and soy, casein, and lactalbumin hydrolysates at a concentration of 0.1 per cent, the development of microorganisms was prevented and a significant decrease in attractiveness resulted. Olfactometer tests showed that when *Lederplex* with *Zephiran* was compared with freshly prepared *Lederplex* there was no repellent effect due to *Zephiran.*

Olfactometer tests failed to indicate any superiority of *Lederplex* over the standard bait at the same time field tests were showing large differences in the catches obtained with these two baits. In the olfactometer tests, the *Lederplex* bait was made up just before testing, and during the short period of the test it had no opportunity to develop an active microflora. Samples of *Lederplex* held in the laboratory from 1 to 8 days showed significant gains in attractiveness for at least 7 days. Four-day-old field baits brought in from leeward Oahu and tested in the olfactometer showed no difference between the standard and the *Lederplex* baits, but field baits that had been exposed on windward Oahu for 4 days showed the *Lederplex* to be 1.7 times as good as the standard in an olfactometer test.

These results suggested that the attractants in the proteinaceous baits were produced by microbiological action on the original protein material. Apparently the antibiotics exerted a beneficial selective action on the microflora that developed.

In replicated field tests with the standard bait, *Lederplex*, and *Lederplex* with tyrothrycin and streptomycin added, the catches for each trap were recorded daily for five successive days. Of the 36 traps containing *Lederplex*, 2 showed a steady daily increase over the standard bait. One caught 13 times and the other 18 times as many flies as the standard on the fifth day.

The baits in these two traps were combined, and pure cultures of the microflora isolated from the mixture were developed. Fourteen strains or species of microorganisms were found, including five Gram-negative rods, one Gram-negative short rod, two Gram-negative coccobacilli, two Gram-positive rods, three Gram-positive short rods, and one yeast. No one of these organisms appeared to be predominant, indicating a complex and unstable microbiological balance. The appearance of the colonies formed on agar and the type of growth in broth cultures indicated that all were distinct strains or species.

Field tests were made with 1 per cent of soy hydrolysate in water inoculated with the various strains of bacteria. Soy hydrolysate was chosen as the proteinaceous material, since the high cost of *Lederplex* ruled it out as a practical bait material. To each bait 0.5 per cent of dextrose was added to provide readily available carbohydrate for the bacteria. All the B vitamins except B-12 were also added. The baits were prepared by adding 800 cc. of inoculum to each 4 liters of the 1 per cent soy hydrolysate lure. The inoculum was prepared by inoculating 800 cc. of sterile bait with 150 cc. of a pure 24-hour culture in dextrose broth, and then allowing this to incubate for another 24 hours. No effort was made to maintain sterile conditions in the finished bait. However, between tests all traps were washed in soap and water and then rinsed with Chlorox, dilute sulfuric acid, and finally in tap water to remove or kill all bacteria remaining from previous tests. The vessels used in the preparation of baits were cleaned with sulfuric acid-potassium dichromate solution, and then rinsed in tap water. It was expected that the large amount of inoculum used in preparing the baits would suppress the growth of other bacteria present in the bait substrate, or in the tap water that was used to make up the baits. All baits were made up the day before they were used in the field. Each field test lasted 7 days. Flies were collected on the fourth and seventh days.

More of each bait was prepared than was needed for the field tests. The excess bait was kept in the original containers in the laboratory for 10 days, and then tested in the olfactometer. The bacterial cultures that gave the best performance in field and olfactometer tests were retested in 4-day-old *Lederplex* cultures in the olfactometer. The best cultures from these

tests were then tested once more in the olfactometer in 4-day-old soy hydrolysate cultures. The results are presented in table 1. Since different field and olfactometer tests were involved in each series —there were 14 strains of microorganisms —no one LSD value is applicable to all series. All differences were significant except those indicated by asterisks.

Table 1.—Field and olfactometer tests with different bacterial strains cultured on soy hydrolysate and *Lederplex*. Per cent of standard bait mean catch.

Bacterium	Field Tests	Olfactometer Tests		
	Soy Hydrolysate	Soy Hydrolysate	*Lederplex*	Soy Hydrolysate
	1 Week	10 Days	4 Days	4 Days
1	117.9*	133.7*	—	—
2	154.9	99.4*	—	—
4	131.3	242.0	118.2	97.7*
5	193.9	261.0	135.7	146.9
6	199.3	87.7*	—	—
8	141.3*	274.0	119.1	131.1*
11	133.9	86.5*	—	—
13	163.3	75.9	—	—
14	236.8	324.5	226.1	253.2
15–1	170.8	54.7*	—	—
15–2[1]	251.1	51.7*	—	—
16	227.0	68.8*	—	—
22	170.1	197.1	91.8*	—
24	122.6	316.9	86.2*	—

[1] Yeast.

Of these organisms, bacterium 14[5] was selected for further study since its cultures ranked high in attractiveness and gave the most consistent results throughout all test series.

Olfactometer tests were undertaken to determine the effect of pH on 4-day-old pure cultures of bacterium 14. The culture medium contained 1 per cent of soy hydrolysate, 0.5 per cent of dextrose, 0.4 per cent of ammonium phosphate, and complete vitamins (except for B-12) in concentrations approximately the same as indicated previously for the best *Lederplex* bait. The pH of the medium was varied from 5.0 to 10.5 in steps of 0.5. No significant difference in the production of attractants was found for any pH value tested. Other tests showed that a culture period of about 2 weeks at room temperatures (75–80° F.) gives the best results, that no significant difference in attractiveness results from the removal of any one of the B vitamins, and that the dextrose in the culture medium decreases the production of attractants in proportion to the amount used. Apparently soy hydrolysate contains enough B vitamins for the production of attractants, if the vitamins are required. The decrease in attractiveness due to dextrose indicated that the attractants are the product of the utilization of amino acids or other proteinaceous materials in the metabolism of bacterium 14.

Soy Meal-Bacterium 14 Bait.—An investigation was next made to determine whether cheaper materials, especially soy meal, could be substituted for soy hydrolysate. A field test with bacterium 14 cultures on 1 per cent soy hydrolysate, 1.25 per cent soy meal, or 1.25 per cent alkali-hydrolyzed soy meal showed the two soy meal baits to be no better than the standard bait, whereas the soy hydrolysate was four times as good. However, these baits were cultured with bacterium 14 for only 24 hours before exposure in the field, and it was suspected that the soy meal cultures might require more time for the production of attractants than soy hydrolysate cultures because of the physical and chemical condition of the substrate.

In olfactometer tests with 14-day cultures under sterile conditions of bacterium 14 on 1 per cent concentrations of soy hydrolysate and soy meal, and on 1 per cent concentrations of soy meal and soy meal hydrolyzed with alkali, each of the last two baits cooked under 15 pounds' pressure for 1 hour before use, the soy hydrolysate, soy meal, and the cooked soy meal gave equally good results. The cooked alkali-hydrolyzed soy meal culture was only half as attractive as the others, the difference being highly significant. Apparently bacterium 14 was capable of hydrolyzing the soy meal proteins, rendering pre-hydrolysis unnecessary, when the culture period was extended to 2 weeks.

An olfactometer test to determine the optimum concentration of soy meal for the production of attractants in 14-day cultures showed 1 per cent to be significantly better than 3, 4, or 5 per cent but not significantly better than 2 per cent. When all cultures were diluted to 1 per cent for exposure in olfactometer tests, there were no significant differences in attractiveness.

Considerable difficulty had been encountered previously in sterilizing soy meal and water mixtures in the autoclave because of the heavy foaming that tended

[5] Identified as *Proteus* sp. (probably new).

to wet the cotton plugs of the flasks. When sterilization and culture with bacterium 14 were carried out with only 100 cc. of 5 per cent soy meal diluted to 1 per cent in a 500-cc. Erlenmeyer flask, this difficulty was overcome and a shallow culture with a large surface exposed to the air was produced. An olfactometer test showed this shallow culture to be six times as good as the standard bait, by far the largest difference between fermenting and proteinaceous baits that had been encountered in olfactometer tests. The sex ratio was 55.5 per cent females for the standard bait and 48.1 per cent for the shallow soy meal culture, with an LSD of 6.4 per cent. None of the proteinaceous baits tested previously in the field or olfactometer had shown any evidence of sex selectivity. The change from deep culture, largely anaerobic, to shallow, aerobic culture was accompanied by the development of a deep red color. This red color has appeared in all subsequent aerobic soy meal-bacterium 14 cultures, but it has never been observed in deep, anaerobic cultures.

In further studies of culture requirements for the soy meal-bacterium 14 bait, the aerobic cultures were always much more attractive than anaerobic cultures. Continual stirring in deep culture was found to give much the same results as the shallow-culture method. Efforts to provide aeration by bubbling air through cultures failed because of excessive foaming. Frequent agitation of shallow cultures, or culturing under an atmosphere of oxygen, did not improve the attractiveness of the bait.

Soy flour produced by grinding meal in a mill gave no better results when cultured with bacterium 14 than the original soy meal. Prefermentation of soy meal with yeast to remove carbohydrates likewise resulted in no improvement. Cultures with 5 and 10 per cent of soy meal, with dilution to 1 per cent before exposure, gave equally good results, and they were better than either more dilute or more concentrated cultures. Large amounts of inoculum were no better than those amounting to 5 per cent of the volume of the water plus soy meal. In field tests 1 per cent of soy meal in the final bait was better than 2 or 4 per cent. There was no difference in attractiveness between 7- and 14-day cultures. In the field soy meal cultures were more effective than soy hydrolysate baits precultured under the same conditions.

The most effective soy meal bait, now designated as SM-14, may be prepared as follows: Place 50 grams of soy meal and 450 cc. of tap water in a 2500-cc. standard Pyrex mold-culture flask, stopper with cotton, and then sterilize by autoclaving at 15 pounds' pressure for 20 minutes. Inoculate this medium by means of a sterile pipette with 25 cc. of a 24-hour pure culture of bacterium 14 in trypticase soy broth, and then hold for 7 days in a room maintained at 80° F. Before use dilute the culture to 5 liters with nonsterile tap water. From this point on make no attempt to maintain sterility, but scrub the traps thoroughly before each usage to avoid build-up of undesirable bacteria.

Refrigeration or quick freezing of the SM-14 bait decreased its effectiveness. When transferred to a sterile 1-quart screw-cap bottle, a 7-day-old culture packed for shipping and then kept in the laboratory for 1 week with frequent agitation was found to be equal in attractiveness to a fresh 7-day-old culture when tested under field conditions. No gas pressure developed in the bottle during the week that it was held in the laboratory.

When the SM-14 bait is used, fly collections should be made twice a week, especially if sex counts are to be made. In a week's time considerable decomposition of flies occurs in the active bacterial medium. Also large numbers of blow flies attracted by the putrefying fruit flies interfere with the effectiveness of the baits and make it difficult to obtain accurate quantitative data.

SM-14 baits gave good performance in the field for 3 weeks without renewal, provided water was added each time fly collections were made to make up for losses due to evaporation.

An effort was made to combine the standard and SM-14 baits. When fresh and 1-week-old standard baits were used to dilute the 10 per cent soy meal culture to 1 per cent, and they were exposed immediately or held for 7 days before exposure, the combined baits were no better than the standard bait. SM-14 baits tested at the same time proved to be four to seven times as good as the standard. Evidently the yeast in the standard bait had removed the attractants produced in

the soy meal culture, suggesting that the attractant or attractants are either fermentable carbohydrates or nitrogenous compounds. It is unlikely that fermentable carbohydrates would be found in soy meal cultures after a 7-day culture period with bacterium 14.

In field tests conducted from May 26 to October 2, 1952, the ratio of attractiveness of the SM-14 bait to that of the standard ranged from 2.8 to 5.4 with an average of 4.1 in June, from 2.1 to 3.9 with an average of 3.2 in July, from 3.3 to 6.4 with an average of 5.2 in August, and from 5.1 to 10.3 with an average of 8.4 in September.

The suggestion of a seasonal effect on the performance of proteinaceous baits had previously been noted in 1950 and 1951. Catches with proteinaceous baits were comparatively high when yeast hydrolysate was first tested in August 1950, and fell off during November and December. In August 1951 there was a sharp rise in the performance of improved proteinaceous baits, which was followed by a decline in October. Field experiments in 1952 yielded evidence that the performance of the SM-14 bait may be significantly affected by trap location.

The factors responsible for variations in performance resulting from season and location of exposure are not yet clearly indicated. Likewise it has not been established whether SM-14 or the standard bait was the more variable. The possible effects of these factors on the validity of oriental fruit fly population estimates made with traps baited with fermenting or proteinaceous baits require further evaluation.

CHEMICAL NATURE OF SM-14 ATTRACTANTS.—In preliminary studies with lyophilization of SM-14 cultures, a procedure in which the water and volatile materials are removed under high vacuum and then condensed in a dry ice-alcohol trap, the attractants remained with the nonvolatile residue. This was strong evidence that ammonia is not the attractant in the SM-14 bait, since the vapor pressure of ammonia at −70° C., the temperature of the dry ice-alcohol trap, is high enough to insure its removal from both residue and condensate under the vacuum used.

The presence of a volatile, noncondensable repellent in the SM-14 bait was also indicated by lyophilization, since both the residue and the recombined residue and condensate were more attractive to the oriental fruit fly than the original culture. Since the attractants were not removed by centrifuging in a supercentrifuge at about 25,000 r.p.m., a procedure that removed the bacteria, it was indicated that they are water-soluble materials.

ATTRACTIVENESS TO OTHER FRUIT FLIES.—Field catches of the Mediterranean fruit fly and the melon fly were much too low to provide accurate quantitative data on the attractiveness of proteinaceous baits to these fruit flies, but recent olfactometer tests indicate that both are attracted to the SM-14 bait much more strongly than to the standard bait, the difference being greater for the melon fly. Catches in Hawaii have indicated that the proteinaceous baits are somewhat specific for dipterous insects. The large numbers of other types of insects found in standard fermenting bait catches rarely occur in proteinaceous-baited traps.

SUMMARY.—A study was undertaken in Hawaii to find a more effective bait for the oriental fruit fly, *Dacus dorsalis* Hendel. Ammonia was only mildly attractive and tended to obscure the effectiveness of other attractants. Yeast, soy, lactalbumin, and casein hydrolysates, and a vitamin-B preparation called *Lederplex* were all attractive to this fruit fly, soy hydrolysate being somewhat superior to the others. None of the B vitamins in *Lederplex*, alone or in combination, were effective attractants.

The attraction of proteinaceous materials appears to be due chiefly to products of microbiological action. Of 14 strains of microorganisms isolated from effective proteinaceous baits, a species of *Proteus* consistently gave the best results when cultured on proteinaceous materials. The pH values between 5.0 and 10.5 did not affect the production of attractants by this bacterium. A 2-week culture period produced the most effective baits. The addition of as little as 0.5 per cent of dextrose to a soy hydrolysate culture medium depressed the attractiveness of the baits materially, indicating that the production of attractants is associated with the utilization of proteinaceous materials as a source of energy in metabolism. A soy meal bait precultured for 1 week with the bacterium proved superior to soy hydroly-

sate, and when aerobic culture conditions were provided the production of attractants from soy meal was increased.

Variations in the performances of soy meal baits were encountered, which appeared to be associated with both seasonal and locational factors.

When the ammonia produced in soy meal cultures was removed, there was an improvement in the performance of the bait, indicating that ammonia at best is only a mild attractant for the oriental fruit fly and that at some concentrations it may actually be repellent. Apparently the attractive portion of the soy meal-bacterium 14 bait is not volatile, since it was not removed under high vacuum. The attractants are also believed to be water-soluble.

The soy meal-bacterium 14 bait (SM-14) also proved to be attractive to the melon fly, *Dacus cucurbitae* Coq., and the Mediterranean fruit fly, *Ceratitis capitata* (Wied.).

The over-all performance of the SM-14 bait in attracting female oriental fruit flies is superior to that of other baits tested in Hawaii, but catches in traps containing this material have not been large enough for practical control purposes. Isolation of the attractants in the bait and elimination of any repellents may lead to a more effective and useful material.

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Codling Moth and Orange Tortrix Control on Apricots in California, 1948–1953

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In California, codling moth has been a major pest of apples and pears for many years. It has also been reported as occasionally attacking plums, prunes, cherries, peaches, nectarines and apricots, but seldom in damaging numbers. Bovey (1949) reported it as a pest of apricots in France. During 1947, there were reports of widespread damage to apricots in the central coast counties of California, especially in the Santa Clara Valley. In 1948, field research on this problem was begun by the Department of Entomology and Parasitology.

Apricots are regularly sprayed in the pink bud or jacket stage with either DDT or basic lead arsenate for control of twig borer and such leaf feeding insects as tussock moth and fruit tree leaf roller. No subsequent sprays of these insecticides are usually applied. The possibility of additional sprays for codling moth would certainly bring about a residue problem, since apricots ripen early in July, and the nature of the fruit would make residue removal difficult.

TESTS IN 1948.—An experimental plot was established in an apricot orchard which had shown close to 50 per cent damaged fruit the previous season. Bait pans were set out in the orchard to determine the peak of codling moth activity. Treatments were applied on April 1, when the fruit was in the jacket stage, and on May 6 when most of the fruit was out of the jacket stage and showed considerable growth. Each treatment was applied to five trees, replicated twice within the experimental block. Applications were made with conventional ground equipment and short orchard guns. The average gallonage applied was 9.5 gallons per tree. At harvest, 500 fruits were examined from each treatment, and the percentage of wormy fruit calculated. Residue analyses were made after each spray application, and at harvest. Treatments, dosages, percentage wormy fruit and residue analyses are expressed in table 1.

The results showed that DDT, TDE, or parathion would give satisfactory control of the codling moth. Bait pan catches for the season showed that activity of the moths began in late April or early May, reaching a peak in mid-May. This pattern of flight was more similar to that obtained in walnuts than in apples and pears. Since the 1948 season was cool, with more than usual rainfall, it was thought that unusual seasonal conditions could have been responsible for this flight pattern.

Table 1.—Control of codling moth on apricots, 1948.

Materials Used	Pounds per 100 Gallons	Application Dates	At Harvest	
			Wormy Fruit (Per Cent)	Residues (P.P.M.)
DDT, 50% wettable	1.5	April 1 May 6	2.6	trace
DDT, 50% wettable	1.5	May 6	2.8	trace
TDE, 50% wettable	2	April 1 May 6	2.0	3.7
Parathion, 15% wettable	3	April 1 May 6	4.0	0.02
Basic Lead Arsenate	4	April 1 May 6	8.0	5.4
Check	—	—	34.0	—

Although residue analyses showed that harvest residues were low, the canning industries, since there was no tolerance set upon apricots, recommended that DDT and TDE not be used on apricots later than the jacket period. This decision was based on the fact that the major portion of the apricot crop is canned, and since apricots are picked ripe, residue removal by washing is very difficult. In addition, part of the crop is dried unwashed, which also creates a residue problem.

TESTS IN 1949.—Another experimental block was set up in 1949 in order to test material that would be less apt to bring about a residue problem. An orchard near Campbell was selected as it was reported to have had a high percentage of wormy fruit the previous season. Single tree plots were used, replicated nine times, and randomized throughout the experimental block. Materials were applied with conventional ground equipment and short orchard guns. Gallonage applied averaged about 10 gallons per tree. Residue analyses were made on both fresh fruit at harvest, and on dried fruit. Materials used, dosages, percentage wormy fruit

Table 2.—Control of codling moth on apricots, 1949.

Wettable Materials Used	Pounds per 100 Gallons	Application Dates	Wormy Fruit at Harvest (Per Cent)	Residue in p.p.m.	
				Fresh Fruit	Dried Fruit
Parathion, 25%	2	April 5 May 4	2.2	0.16	0.0
Parathion, 25%	3	April 5 May 4	1.9	0.18	0.0
Methoxychlor, 50%	3	April 5 May 4	0.6	9.3[1]	1.8
TDE, 50%	2	April 5 May 4	1.9	2.6	7.1
DDT, 50% Parathion, 25%	1.5 3	April 5 May 4	1.9	0.09 (parathion)	0.0 (parathion)
DDT, 50% Methoxychlor, 50%	1.5 3	April 5 May 4	0.7	4.5 (methoxychlor)	2.2 (methoxychlor)
DDT, 50% TDE, 50%	1.5 2	April 5 May 4	1.6	2.6 (DDT+TDE)	5.0 (DDT+TDE)
Check	—	—	6.0	—	—

[1] Analysis seems to be in error, as it is too high as compared with other analytical data.

and residue data are expressed in table 2. The results indicate that parathion, methoxychlor, and TDE gave adequate control either as two sprays, or as a single treatment in May following an application of DDT in the jacket stage. Residue data indicated that parathion would not leave an objectionable residue at harvest, but TDE left a residue which was increased on the dried fruit. Methoxychlor, although leaving a residue, might be safe, as the human toxicity of the compound is quite low.

Bait pan catches for the season showed that, as in 1948, moths began flight in early May, reaching a peak during the middle of May, and tapering off into June. Evidently moth flight in apricots is not the same as in apples and pears, but approximates the pattern observed in walnuts. It was evident, therefore, that the May spray was the critical one from the standpoint of timing. The petal fall spray, however, was of importance in controlling other insects which attack apricots during this period. It was also noted at harvest that orange tortrix was responsible for a small degree of damage to the apricots, although populations were relatively low.

TESTS IN 1951.—During 1950, no experimental work was done on the problem. Surveys of orchards at harvest, however, indicated that orange tortrix had increased, while codling moth was encountered as a pest in relatively few orchards. Since methoxychlor had shown so much promise against codling moth in 1949, the material was applied in a series of plots in 1951 to test both timing and dosage. An orchard was selected in Sunnyvale which had been reported as having considerable worm damage in 1949. In this plot, large blocks were used, consisting of 12 trees each, and each block was replicated three times. Materials were applied with conventional ground equipment. Applied gallonage averaged about 700 gallons per acre. Applications were made at various timings and combinations, starting with the pink bud period, and going into June.

At harvest, approximately 2000 fruit were examined from each treatment. It was noted that very few codling moth injured fruit were present, and that orange tortrix was responsible for most of the damaged fruit. Codling moth damage is characterized by holes in the apricots, penetrating to the pit. When opened, a

Table 3.—Control of codling moth and orange tortrix on apricots, 1951.

Wettable Material Used	Pounds Used	Application Dates	Per Cent Wormy Fruit	
			Codling moth	Orange tortrix
DDT, 50%	1½	March 31	0.0	2.7
Methoxychlor, 50%	2	May 22		
DDT, 50%	1½	April 6	0.0	1.6
Methoxychlor, 50%	2	May 22		
Methoxychlor, 50%	2	May 22	0.0	3.4
Methoxychlor, 50%	2	May 22	0.0	2.3
Parathion, 25%	2	June 19		
Check	—	—	1.3	8.0

[1] Pink bud period.

damaged apricot shows considerable feeding around the pit, with much frass, and in addition fungus growth causes the feeding area to become black. Orange tortrix, on the other hand, is a shallow feeder, and attack is characterized by shallow feeding areas on the sides of the fruit, or more often, around the stem end. Materials used, dosages, dates of application and percentage damaged fruit from both codling moth and orange tortrix are shown in table 3. Codling moth infestations were too low to gain any information from these plots. It was significant, however, that orange tortrix had become the major pest in this orchard. There was little difference between treatments in the control of orange tortrix, but all treatments reduced the population in comparison with the checks.

TESTS IN 1952.—The work from 1948 to 1951 resulted in a suggested spray program for apricot growers consisting of a petal fall spray of DDT, followed by a May spray of either parathion or methoxychlor. The timing of this May spray would be based upon bait pan records of the codling moth flight. Following the 1951 season, the question was raised by growers and canners as to whether or not the program developed for codling moth would also be effective against the orange tortrix, since by that time it had become the major insect problem in apricots. Because of the orange tortrix situation, the spray program was revised to substitute TDE for DDT in the jacket spray, and use parathion rather than methoxychlor in the May spray. Previous work on orange tortrix control on apples had indicated that TDE and parathion were more effective than DDT or methoxychlor (Borden & Madsen 1949).

FIG. 1.—Codling moth larva and damage to apricot.

FIG. 2.—Orange tortrix larva and damage to apricot.

In 1952, a series of plots were established in which growers applied treatments according to the suggested program. The timing of the May spray was determined by bait pans set up in various areas within the Santa Clara Valley. At harvest, counts were made of the wormy fruit in treated orchards, and compared to orchards in which the suggested spray programs were not followed. The results of these plots are shown in table 4. Percentage wormy fruit was entirely due to orange tortrix in these plots, no codling moth was involved. The 1952 work indicated that a petal fall treatment of TDE followed by a May spray of parathion timed to bait pan records will control both the orange tortrix and codling moth, as well as other fruit feeding insects.

Table 4.—Control of orange tortrix on apricots, 1952.

Location	Spray Program[1]			Wormy Fruit at Harvest (Per Cent)
	Pink Bud	Petal Fall	May	
Sunnyvale	DDT	TDE	Parathion	0.0
Sunnyvale	DDT	TDE	Parathion	0.0
Cupertino	DDT	TDE	Parathion	0.0
Mountain View	—	DDT	Parathion	0.2
Cupertino	DDT	—	Parathion	0.5
San Jose	TDE	—	Parathion	0.4
Sunnyvale	DDT	TDE	—	0.6
Mountain View	DDT	TDE	—	1.1
East Foothills	—	DDT	—	3.2
East Foothills	—	Lead Arsenate	—	3.4
Sunnyvale	—	—	Parathion dust	4.8
Sunnyvale	—	—	—	5.2
Mountain View	—	—	—	11.4

[1] Applied by growers.

The inclusion of DDT in the pink bud Bordeaux spray is a common practice among apricot growers for twig borer control, but this timing will not aid in either codling moth or orange tortrix control. Even though codling moth has declined as a major pest on apricots in recent years, it could come back as a problem, and for that reason the May spray should be timed for codling moth control, since the 1952 work demonstrated that this timing will also control orange tortrix.

Tests in 1953.—Work was continued on orange tortrix control in 1953 in the hope of finding substitute materials for parathion in the May spray. The high human toxicity of parathion has caused many growers to hesitate in using this compound. A plot was established at Berryessa, California, in an orchard which had considerable damage from tortrix the previous season. The new materials tested were malathion and *Perthane* (Q-137). Malathion had shown promise against a variety of insect pests and has a low human toxicity. *Perthane*, although a chlorinated hydrocarbon which would probably leave a residue at harvest, has a very low human toxicity rating. A timing plot was also included, to see if a June spray rather than a May spray would be more effective in orange tortrix control.

Twelve tree plots were used for each treatment, and replicated twice. Materials were applied with conventional ground equipment, and approximately 600 gallons of spray per acre were applied. Applications were made on March 17 and May 18. One plot received an application on June 10. At harvest on July 5, 1000 fruit per plot were examined for insect damage. Orange tortrix, twig borer and an occasional codling moth were the insects responsible for fruit injury. At the same time, samples of fruit were collected for residue analyses. Materials used, dosages per 100 gallons, time of application, percentage wormy fruit, and residue analyses are expressed in table 5.

These data indicate that malathion is as effective against the orange tortrix as parathion, and could be substituted for parathion in the May spray if grower applications substantiate these results. There is apparently no residue problem with the use of malathion. *Perthane*, although reducing the worm count below the check, did not measure up to either parathion or malathion. There was no significant difference between the May and June spray of parathion on these plots. Since the May spray is the proper timing for codling moth, it would be advantageous to retain this timing, since codling moth may again become a major pest. In addition, it will reduce the possibility of any residue problem at harvest.

Summary.—In 1948, experimental work was begun on control of codling moth in apricots. The experimental work over 1948 to 1950 resulted in the development of a spray program consisting of DDT or TDE at the petal fall stage followed by methoxychlor or parathion treatment in May. Since 1950, codling moth popula-

Table 5.—Control of orange tortrix on apricots, 1953.

Materials Used	Pounds per 100 Gallons	Application Dates	Worms per 1000 Fruit			Per Cent Wormy	Residue, p.p.m.
			Tortrix	Codling Moth	Twig Borer		
TDE, 50% Parathion, 25%	2 2	Mar. 17 May 18	0	0	5	0.5	0.0 (Parathion)
TDE, 50% Parathion, 25%	2 2	Mar. 17 June 10	1	0	5	0.6	0.12 (Parathion)
TDE, 50% Malathion, 25%	2 4	Mar. 17 May 18	0	0	7	0.7	0.0 (Malathion)
Perthane, 25% Perthane, 25%	4 4	Mar. 17 May 18	21	1	9	3.1	2.43
Check	—	—	54	1	21	7.6	—

tions have declined in apricots, and orange tortrix has become the major pest. The increase in orange tortrix resulted in a change in the program, in that TDE at petal fall and parathion in May were the preferred materials. Timing of the May treatment is most important, and experiments showed that if the May spray were timed to codling moth flights, it would also adequately control orange tortrix. Tests in 1953 indicate that malathion is as effective as parathion for orange tortrix control.

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Persistence of Chlordane in Soils of the Area Infested by the Japanese Beetle

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Chlordane at the rate of 100 pounds per acre is recommended by the Entomology Research Branch for the protection of turf from grubs of the Japanese beetle, *Popillia japonica* Newm. (Fleming 1950). It is authorized also for the treatment of soil in commercial nurseries to satisfy the requirements of the quarantine because of this insect.

An investigation was begun in 1947 at the Japanese beetle laboratory to determine the persistence of chlordane in soils of the area infested by this insect. Chemical analyses and biosassays have been made of soil samples from experimental plots established in 1947 and 1948 at Moorestown and Blairstown, N. J., Philadelphia, Pa., New London and Orange, Conn., and Deerfield, Mass., and from representative soils collected and brought to the laboratory. A preliminary report on this work has been presented (Fleming *et. al.* 1951).

[1] The soils used in the laboratory study were obtained through the cooperation of the agricultural experiment stations of Connecticut, Massachusetts, New York, Ohio, and Rhode Island, and of the Northeastern Region of the Entomology Research Branch. L. W. Coles, C. A. Perkins, and H. W. Strabel, of the Branch's Japanese beetle laboratory, at Moorestown, N. J., assisted in the bioassays and other phases of the investigation; the chemical analyses of the soil samples were made by R. D. Chisholm and L. Koblitsky of this Branch.

PERSISTENCE IN TREATED TURF.—In 1947 and 1948 chlordane at the rate of approximately 10 pounds per acre was applied as a top dressing to plots of turf, from $\frac{1}{4}$ acre to several acres in size, at locations between Philadelphia, Pa., and Deerfield, Mass. Usually the toxicant was applied as a 5 per cent dust with a fertilizer spreader, but in a few experiments it was applied as a suspension or emulsion with an hydraulic sprayer. Since no difference was noted in the insecticidal effectiveness of the various formulations, no differentiation is made between them in this report. The turf was mowed and cared for according to the usual practice at the golf course, college, academy, or parkway where the plots were located.

In 1948 and 1949 samples were taken from the Moorestown plots for chemical analyses, and in subsequent years from as many plots as possible for chemical analyses and bioassays. Each sample was a composite of 100 borings, each 2 inches in diameter and 3 inches in depth, taken systematically over the treated area. Previous analyses had shown that all the chlordane applied as a top dressing to established turf remained within the first 3 inches of soil.

The total organic chlorine in each sample was determined by the method developed by Koblitsky and Chisholm (1949), and the amount of chlordane, expressed as pounds per 3-inch acre, was calculated by multiplying the total organic chlorine by the factor 1.56.

For the biosssays standards of insecticidal action were prepared by mixing chlordane intimately with soil at rates of 21, 42, 83, and 208 mg. per cubic foot, which were equivalent to 0.5, 1, 2, and 5 pounds per 3-inch acre. Third-instar Japanese beetle larvae served as the test insects and 100 were introduced into each standard and into each sample. A week later the survivors were counted. After the process had been repeated two or three times, the average survival in each sample was compared with that in the standards, and by interpolation the amount of residual chlordane in each sample was determined.

The results obtained by chemical analyses and bioassays were grouped by 6-month intervals according to the periods between the application of the treatment and sampling. The average amount of residual chlordane for each period, rounded to the nearest 0.5 pound, is given in table 1.

Table 1.—Persistence of chlordane after application as a top dressing at the rate of 10 pounds per acre to established turf.

Months After Treatment	Number of Samples	Average Residual Chlordane, Pounds per Acre	
		Chemical Analysis	Bioassay
6	2	8.0	—
18	2	3.0	—
30	5	.5	0.5
36	1	1.5	.5
42	8	1.5	.5
54	6	1.0	.5
66	2	1.0	.5

The amount of residual chlordane decreased rapidly during the first 30 months, about one-third remaining after 18 months and about one-twentieth at the end of this period. There was apparently little change during the next 36 months, although the amounts remaining were within the limits of accuracy of the chemical and biological methods.

EFFECT OF RATE OF APPLICATION.—Chlordane was mixed intimately with Sassafras sandy loam at various rates per 3-inch acre to study the effect of the rate of application on persistence. Most of the year the treated soil was exposed to weathering in pots in the field. During the winter bioassays were made with third-instar Japanese beetle larvae to determine the amount of residual chlordane after intervals of 1 to 5 years. The results are presented in table 2.

Within the range of concentrations tested, the amount of chlordane remaining in the soil in general was proportional to the amount applied. The percentage reduction was much the same for the different amounts of chlordane over a 5-year

Table 2.—Effect of rate of application on the persistence of chlordane in soil.

Pounds Applied per 3-Inch Acre	Per Cent of Residual Chlordane After—				
	1 Year	2 Years	3 Years	4 Years	5 Years
1	41	20	11	—	—
2	42	23	13	6	—
5	44	23	13	6	2
10	48	32	17	8	4
25	—	32	15	6	3
Average	44	26	14	6	3

Table 3.—Persistence of chlordane in different series of soils.

SOIL SERIES	AVERAGE PER CENT OF RESIDUAL CHLORDANE AFTER—			
	1 Year	2 Years	3 Years	4 Years
Agawam, Colts Neck, Appling, Helena, Cecil, Penn, Cheshire	84	50	18	4
Collington, Ondawa, Dunellen, Pittsfield, Hagerstown, Portsmouth, Lansdale, St. Johns, Marlboro	73	40	16	5
Berks, Gloucester, Charlton, Merrimac, Chester, Narragansett, Chicopee, Sassafras, Georgeville, Woodbridge	63	31	13	5
Bridgehampton, Keyport, Caneadea, Lakewood, Croton, Mahoning, Davidson, Suffield, Durham, Washington, Elkton, Wauseon, Hadley, Woodstown, Iredell	54	25	11	5
Bernardston, Hartford, Brookston, Mentor, Chenango, Paxton, Coloma, Shrewsbury, Dover, Toledo, Essex, Whippany	43	18	9	5
Berrien, Penwood, Lorain, Reynolds, Newfield, Wethersfield, Ontario, Wingdale, Painesville	35	18	9	5
Brookfield, Plymouth, Menlo	23	10	5	3
Average	56	28	12	5

period. When chlordane was mixed with soil, the reduction in the residue was slower than when it was applied as a top dressing to turf. The residue was not reduced to about one-twentieth of the original amount until after 4 years.

PERSISTENCE IN DIFFERENT SOILS.—Chlordane was mixed intimately at the rate of 10 pounds per 3-inch acre with 83 mineral soils from the area infested by the Japanese beetle in a study of the persistence of the toxicant in different soils. Fifteen of the soils were from Connecticut, 12 from Massachusetts, 3 from Rhode Island, 2 from New York, 15 from Ohio, 28 from New Jersey, and 8 from North Carolina.

Bioassays were made to determine the residual chlordane after 1, 2, 3, and 4 years. The soils, which were members of 65 representative series, were grouped according to the amount of residual chlordane, as shown in table 3. In view of the variations in the residual chlordane in these groups during the first 3 years, further consideration was given to the factors that might be involved.

EFFECT OF THE AREA OF SOIL ORIGIN.—The 83 mineral soils were grouped according to the general area of their origin, and the average residual chlordane was determined from each such area annually for 4 years. These results are summarized in table 4. At the end of the first year the amount of residual chlordane in the soils varied with the area of their origin. These differences became progressively less until after 4 years about the same amount of residual chlordane occurred in all of them.

EFFECT OF ORGANIC MATTER.—It seemed possible that the persistence of chlordane in soil might have been influenced by the organic matter present. Little information was available on the organic content of the soils used, but the nitrogen content of 51 of them had been determined by various investigators (Lipman *et al.* 1940, Joffe & Conybeare 1943).

The organic matter probably present was estimated by multiplying the percent-

Table 4.—Persistence of chlordane in soil from different general areas.

AREA	NUMBER OF SOILS	PER CENT OF RESIDUAL CHLORDANE AFTER—			
		1 Year	2 Years	3 Years	4 Years
Northern Ohio	15	42	20	11	6
Southern New England	30	51	25	11	4
New York	2	54	24	11	5
New Jersey	28	65	34	14	5
North Carolina	8	70	33	16	7
Average		56	28	12	5

age of nitrogen reported present in representative samples by the factor 17.24, a method used by pedologists. The soils were then grouped according to their estimated percentage of organic matter, and the average residual chlordane was determined for each group. These data, presented in table 5, show that in general the more organic matter assumed to be present the less residual chlordane was found during the first 3 years. The differences between these groups became progressively less until after 4 years about the same amount of residual chlordane occurred in all of them.

Table 5.—Effect of organic matter in the soil on persistence of chlordane.

Assumed Per Cent Organic Matter	Number of Soils	Per Cent of Residual Chlordane After—			
		1 Year	2 Years	3 Years	4 Years
0– 1	6	65	30	15	7
1– 2	7	72	42	17	5
2– 3	24	55	26	11	4
3– 4	7	50	28	11	4
4– 5	5	53	24	11	5
5– 6	1	21	9	5	2
25–30	1	18	9	4	3

Effect of Other Soil Constituents.—Fairly complete soil analyses have been made by several investigators on 24 of the series of soils used in this study (Lipman *et al.* 1940, Joffe & Conybeare 1943). The soils were grouped according to the percentage of phosphorus, potassium, calcium, magnesium, iron, aluminum, and silica, and the relation of each element to the residual chlordane was determined. There appeared to be no relation between these elements and the residual chlordane.

Effect of Texture.—It was suspected that the texture of the soil might affect the amount of residual chlordane. The soils were grouped according to texture, and the average residual chlordane for each group was determined at various intervals. The results, presented in table 6, do not indicate that texture was an important factor.

Table 6.—Effect of texture on persistence of chlordane in soil.

Texture of Soils	Number of Soils	Per Cent of Residual Chlordane After—			
		1 Year	2 Years	3 Years	4 Years
Sands, shales, and gravelly loams	9	61	32	15	7
Sandy loams	38	59	31	13	5
Loams	19	51	25	11	5
Silt loams	12	55	25	10	4
Clay loams	5	45	24	13	6
Average		56	28	12	5

Summary.—An investigation was begun in 1947 of the persistence of chlordane in soils of the region infested by the Japanese beetle, *Popillia japonica* Newm. Experimental plots were established at Moorestown and Blairstown, N. J., Philadelphia, Pa., Orange and New London, Conn., and Deerfield, Mass., and studies were conducted with 83 representative mineral soils from Connecticut, Massachusetts, Rhode Island, New York, Ohio, New Jersey, and North Carolina. The residual chlordane was determined by chemical analyses and bioassays, in which third-instar Japanese beetle larvae served as test insects.

When chlordane was applied at the rate of approximately 10 pounds per acre as a top dressing to established turf, about one-third remained after $1\frac{1}{2}$ years and about one-twentieth after $2\frac{1}{2}$ years, but there was little change in the residue during the next 3 years. When chlordane was mixed with soil at rates varying from 1 to 25 pounds per acre and exposed to weathering in pots, the amount of residue during a 5-year period was proportional to the amount applied, but the rate of reduction was slower.

There was considerable variation in the residual chlordane in 83 mineral soils. In the most retentive group 84 per cent remained after 1 year and 50 per cent after 2 years; in the least retentive group only 23 per cent remained after 1 year and 10 per cent after 2 years. The residual chlordane in all the soils tended to approach the general averages of 12 per cent after 3 years and 5 per cent after 4 years. There seemed to be a definite trend for the amount of residual chlordane to be greater in the soils of the southern part of the region than in those of the northern part. The more organic matter estimated to be present, the less residual chlordane was found. With the exception of nitrogen, which is associated with the organic matter, no relation was found between the residual chlordane and the other elements in the soil. The texture of the soil was not an important factor in the persistence of chlordane.

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BOOK REVIEWS

REPORT NO. 27, "A SPRAY DEPOSIT ANALYSER," by E. S. Trickett and R. J. Courshee, National Institute of Agricultural Engineering, October 1953, 35 pp., Bedfordshire, England.

An electronic analyzer for measuring automatically the sizes of stains made by droplets on paper is described. It is essentially a picture telegraph transmitter to scan the paper attached to a group of electric analyzers to record the various size stains as they are scanned. The mathematical theory as well as the electronic arrangement are discussed. This machine is suitable for stains between 0.5 and 8 mm. in diameter.

A. H. YEOMANS

REPORT NO. 31, "A STUDY OF THE METHODS OF MEASURING SMALL SPRAY DROPS," by R. J. Courshee and J. B. Byass, National Institute of Agricultural Engineering, Sept. 1953, 8 pp., Bedfordshire, England.

Water sprays are caught in a grease mixture (by weight 24% vaseline; 76% medicinal paraffin) then covered with medicinal paraffin for direct measurement under a microscope. The evaporation rates of water droplets between 50 and 500 μ diameter are studied under laboratory conditions. The difficulties of using magnesium oxide coated slides are noted with emphasis on the bouncing of droplets larger than 100 μ diameter from this type of surface.

A. H. YEOMANS

REPORT NO. 32, "PREPARATION AND CALIBRATION OF GLASS SLIDES FOR SAMPLING SPRAYS," by R. J. Courshee and J. B. Byass, National Institute of Agricultural Engineering, Oct. 1953, 5 pp., Bedfordshire, England.

A method of preparing microscope slides with "Autobrite," a silicon auto polish, is described. The "Autobrite" is rubbed on, allowed to dry and then polished with tissue paper. These slides are then good between 1 day and 1 week after preparation. Water droplets containing 3% by weight nigrosine dye are calibrated on this type of slide between 50 and 600 μ diameter. At 300 μ the stain size is roughly 500 μ and at 600 μ the stain size is 1200 μ.

A. H. YEOMANS

SCIENTIFIC NOTES

A Method of Collecting Large Quantities of Feces from Triatominae Infected with *Trypanosoma cruzi*[1]

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When Triatominae feed to repletion on blood a large portion of the water in the ingested blood is rapidly passed from the insect's body; the formed portion of the blood is retained and digested. If the bugs are infected with *Trypanosoma cruzi* Chagas, many of the intestinal forms are flushed from the hind gut in the excreted water and feces. The author has experienced some difficulty in obtaining one or more cubic centimeters of fecal inoculum for transmission studies when several mammalian hosts were to be infected. Infected bugs can be killed and the contents of the hind gut collected; this is not a recommended procedure because the source of the inoculum is terminated and undigested blood frequently is mixed with the inoculum.

For transmission studies the author has found it desirable to maintain colonies of from 30 to 50 bugs each. When using *Triatoma infestans* (Klug) or other large species that defecate rapidly after feeding, 30 individuals per colony are quite adequate; however, when colonies of *Triatoma protracta* (Uhler) are used or other small species that defecate relatively slowly after feeding, 50 or more bugs per colony are required.

Figure 1 illustrates the method used to collect infective feces from *Triatoma*. This jar was constructed from a plastic tube 10 centimeters long and 9 centimeters in diameter, inside measurement. The plastic stock used was seven-tenths of a centimeter in thickness. Both ends of the tube were threaded to fit a Mason screw cap band. The upper screw cap band was then covered with nylon and held in place by adhesive tape as shown in figure 1. The lower aperture of the jar was covered by a standard Mason lid and screw cap band.

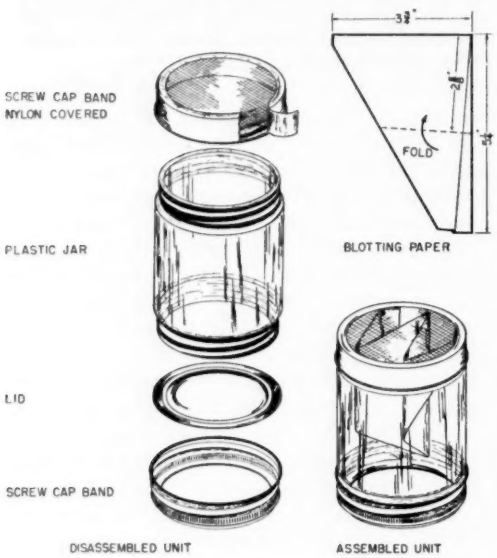

FIG. 1

If *Triatoma* are not too crowded when they are released on the blotting paper, they will remain on the paper; these bugs cannot climb on smooth plastic surfaces. The blotting paper is held in place by a small piece of adhesive tape attached to the upper rim of the jar. When uninfected bugs are to be infected, a mammalian host, usually an infected rat, can be strapped over the upper aperture of the jar; this is best achieved by wrapping the rat in surgical gauze and securing the entire cloth and animal in position by strips of adhesive tape running from one side of the jar over the animal to the opposite side of the jar.

Infective feces may be collected from Triatominae from 20 to 30 days after they have fed on an infected host. When infective feces are needed for inoculation purposes the infected colony may be fed on a rabbit using the feeding device described by Ryckman (1952). During and immediately after feeding *Triatoma* face upward, the fecal drops fall uninterrupted to the bottom of the jar. When many droplets of feces have accumulated they may be readily picked up with a Kline antigen pipette. If *T. infestans*, or a species of similar defecation habits is used, it is recommended that the lower screw cap band and lid be removed and the jar be set over a petri dish to collect several cubic centimeters of infective feces. The infective feces can then readily be injected into young rats by intraperitoneal injection. Rearing a colony of infected bugs is the most practical method of maintaining a strain of *T. cruzi* because once infected, *Triatoma* remain infected for life, frequently a year or more.

Advantages of this type of feeding device are:

1. The infected bugs are not sacrificed and may be used for repeated transmission studies. Once infected, a colony of bugs are a source of infective inoculum for a year or more.

2. Foreign proteins in the form of undigested blood do not contaminate the inoculum as frequently occurs when feces are obtained by killing the bugs and removing the hind gut contents.

3. Large quantities of infective feces may be obtained quickly for transmission studies.

4. Uninfected laboratory animals do not become infected as a result of being fed upon by infected bugs because the bugs feed in an upward direction with all feces falling away from the host.

This type of feeding unit may also be used as a rearing unit with limited modifications which are: (1) Extension of the blotting paper for the full length of the jar, *i.e.* from the upper lid to the bottom of the jar. (2) A disc of blotting paper or absorbent paper toweling should be placed over the bottom lid inside the jar to absorb the feces.

Triatominae eggs, of all species laying smooth eggs, are readily collected by removing the bottom screw cap band. Females of *Rhodnius prolixus* Stål and a limited number of species in the genus *Tria-*

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[1] This investigation was supported by a research grant (E-173) from the National Institutes of Health, U. S. Public Health Service, Department of Health, Education, and Welfare

toma attach their eggs firmly to the blotter paper or similar material; eggs of these species must be removed from the blotting paper by mechanical means.

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Control of Brown-Tail Moth with a Portable Fog Generator

D. BOOCOCK[1]

The use of fog or thermal aerosol generators for controlling certain insect pests is now well established and a number of different machines are available. The latest machine is a portable apparatus, described by Plate (1952) and Boocock (1953) and known as *SWINGFOG*,[2] which can be easily carried and operated by one man. It creates fog by atomising an insecticide solution into a stream of hot gas produced by a pulse-jet engine. The machine weighs about 24 lbs. dry and the insecticide tank holds a little over one U. S. gallon. The insecticide output is 2½ to 3½ U. S. gallons per hour. As the *SWINGFOG* generator has recently been introduced in the United States the field test described herein may be of interest.

An outbreak of larvae of the brown-tail moth, *Nygmia phaeorrhoea* (Donov.), occurred in 1953 at Peacehaven on the south coast of England about 6 miles from Brighton and became a very severe nuisance. The infestation originated on gorze bushes and brambles on uncultivated land. The larvae had appeared in the 2 previous years but by no means in such large numbers. This year's heavy outbreak covering about 200 acres was probably due to the mild winter and the warm spring weather. The larvae spread to gardens, hedges and footpaths and invaded houses even getting into beds and children's cots and perambulators. Apart from their nuisance value they have caused severe irritating rashes on the skin of some people.

Control measures were taken by the Public Health Department of the Chailey Rural District Council and included cutting, clearing and burning of herbage, and spraying with DDT wettable powders, emulsions and solutions. The DDT spraying, whilst effective against exposed larvae proved somewhat expensive and was ineffective against larvae sheltering in the center and underneath brambles and gorze. *SWINGFOG* was used to overcome this difficulty as it proved easy to insert the fog outlet tube of the machine into the host plants and thus envelop them for a minute or two in insecticidal fog. It is obviously important when using *SWINGFOG*, as with other fogging machines (Langford & Vincent 1948, Ossowski 1952) to envelop the pest and the plants or products infested with fog of suitable insecticidal concentration for a sufficient period of time.

The following tests were carried out to check the efficiency of *SWINGFOG* against *Nygmia* larvae using *Standardised Swingfog Solution D.10* which contains 10 per cent DDT (75 to 80% p,p′-isomer) in fog oil.

For convenience of carrying out estimations a spindle tree hedge, *Euonymus europaesis*, heavily infested with larvae was selected for the test. Many of the leaves had three or four larvae feeding on them at one time. Eight yards of hedge were treated. The *SWINGFOG* machine was carried past the hedge twice and the fog passed over each part of it for about 1 minute. The outlet of the machine was about 2 feet from the hedge. Conditions were far from being favorable for fogging. It was 4 P.M. British Summer Time, the sun was shining brightly, and there was a strong variable breeze (5 to 10 m.p.h.).

Within 10 minutes after fogging there was a very marked reduction in the number of larvae on the hedge, the affected larvae having fallen to the ground. A rough visual estimate of the reduction

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[1] Chief Entomologist, The Standardised Disinfectants Co., Ltd., London, England.

[2] Devenco Incorporated, 150 Broadway, New York 38, N. Y., sole licensee for North America, the Philippines, and most of the islands of the Caribbean; Messrs. Swingfire Limited, 94–98 Petty France, London, S.W. 1, England, sole concessionaires for the British Commonwealth of Nations.

Table 1.—Effect of DDT Fog on Larvae of Brown-tail moth.

	Mortality Estimations After								
	24 Hours			48 Hours			3 Days		
	D[1]	A[2]	H[3]	D	A	H	D	A	H
Fogged larvae	15	9	0	17	7	0	24	0	0
Control larvae	0	0	19	0	0	19	0	0	19
Foliage collected 24 hours after fogging	7	9	3	16	2	1	18	1	0
Untreated foliage	0	0	20	1	3	16	3	3	14
Foliage collected 7 days after fogging				4	7	15	5	3	18
Untreated foliage				0	0	32	0	1	31

[1] Dead—no movement or only occasional twitches.
[2] Affected—constant purposeless twitching and wriggling.
[3] Healthy—normal behavior; purposeful directional movement.

would be 80 to 90 per cent. A number of the fallen larvae were collected and placed for observation in a glass dish with a gauze cover along with *Euonymus* leaves which had not been fogged. Larvae had also been collected before fogging to serve as controls. The difference in behavior of the fogged and control larvae was marked. The controls fed vigorously on the leaves provided whereas the fogged larvae lay wriggling in the bottom of the jar and were incapable of crawling onto the leaves and feeding. This is reflected in the observation that the 24 fogged larvae produced only 32 pellets of excreta in 24 hours whereas the 19 untreated larvae produced 528. Mortalities of the fogged and control larvae were estimated after 24 hours, 48 hours and 3 days. The larvae were kept supplied with fresh leaves throughout the period. Larvae in the penultimate instar were used for all tests. Results are given in table 1.

The hedge was examined 24 hours and 7 days after fogging. Search revealed the presence of two healthy larvae on the first occasion and three on the second. The infestation on untreated sections of the hedge was undiminished. To ascertain whether the fog left any active deposit of DDT on the treated foliage, samples were taken 24 hours and 7 days after fogging. The samples were placed in wide-mouthed gauze-covered dishes and healthy larvae which had not been fogged were placed on them. Healthy larvae were also placed on samples of unfogged foliage to serve as controls. The results are shown in table 1.

The mortality on foliage collected 24 hours after fogging (corrected for mortality of controls) was 84 per cent and on foliage collected 7 days after fogging 19 per cent. There was no rain during the first 24 hours but over the next 6 days the rainfall was approximately 0.6 inch. It must be borne in mind that the foliage was only about 2 feet from the fog outlet of the machine.

SUMMARY.—A portable fog generator, *SWINGFOG*, played a useful part in controlling an outbreak of larvae of the brown-tail moth, *Nygmia phaeorrhoea* (Donov.), penetrating to the bottom and center of brambles and bushes where sprays applied by conventional methods fail to penetrate. Tests with a solution containing 10 per cent of DDT showed virtually 100 per cent immediate knockdown and kill of larvae. Enough DDT was deposited on foliage near the outlet of the machine to have some lethal effect up to a week after fogging. It is obviously important to envelop the pest and the plant or product infested with fog of suitable insecticidal concentration long enough to give satisfactory results.

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Insecticides for Tobacco Budworm Control on Shade-Grown Tobacco

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The tobacco budworm, *Heliothis virescens* (F.), is the most serious insect pest of shade-grown tobacco in the Florida-Georgia producing area. For approximately 25 years a poisoned bait applied to the buds of infested tobacco plants with the fingers was the standard control measure for this pest. This bait consisted of a 1–75 mixture of lead arsenate and corn meal (Chamberlin & Madden 1942). It was generally effective, but about two applications were required each week during the growing season until the plants were topped. Much cheap labor was also required. Labor shortages during the last few years have increased the need for an all-purpose insecticide for the control of all insects on tobacco. Experiments were conducted at Quincy, Florida, during the period 1949–1952 to develop such an insecticide. During the course of these experiments information was obtained on the control of the tobacco budworm with dust mixtures.

EXPERIMENT IN 1949.—The 10-per cent DDT dust developed by Allen & Early (1947) for control of the tobacco budworm on flue-cured tobacco was given preliminary tests on shade- and sun-grown cigar tobacco in 1949. These tests indicated that this insecticide applied with rotary hand dusters gave a high degree of budworm control and was safe on cigar-tobacco foliage. Finely ground, sterilized tobacco dust was the most satisfactory diluent for use on this type of tobacco.

EXPERIMENT IN 1950.—A 1-acre field of shade-grown tobacco was used. The plots were 6 rows wide and 38 feet long, and were 8 feet apart. Treatments were arranged in three randomized blocks separated by roadways. To insure a heavy budworm infestation for test purposes, large openings were made in the cloth walls, permitting the entrance of budworm adults.

Dusts containing DDT, TDE, methoxychlor, toxaphene, and parathion were tested. They were prepared from wettable powders. A finely ground, nonalkaline, sterilized tobacco dust from which most of the water-soluble materials had been removed was used as the diluent. The dusts were applied at weekly intervals at about 8 pounds per acre with rotary hand dusters. In the first nine applications the dusts were directed toward the plant buds, but in the last three they were directed to the upper leaves and applied behind the operator to avoid the dust cloud. The standard budworm poisoned bait was applied to the buds with the fingers. Parathion dust was included in all but one of the treatments, as previous investigations had shown that weekly applications of this insecticide usually gave satisfactory aphid control (Chamberlin 1950).

Of 8,100 leaves examined after each treatment, the percentages injured by budworms were as follows:

DDT 10%	0.4
Parathion 1% plus—	
DDT 10%	.3
5%	2.1

[1] The assistance of L. M. May is gratefully acknowledged.
[2] In cooperation with the North Florida Experiment Station, Quincy.

TDE 15%	.4
10%	.7
Poisoned bait (corn meal and lead arsenate, 1–75).	12.3
Methoxychlor 15%	40.6
10%	40.9
Toxaphene 10%	3.9
Parathion 1% (alone)	35.3
Check (no insecticide)	81.9

The only insecticides that held the injury below the 2-per cent level, a protection generally considered satisfactory in this area, contained either DDT or TDE. The inclusion of 1 per cent of parathion with DDT did not increase budworm control appreciably, but served to control a heavy infestation of the green peach aphid, *Myzus persicae* (Sulz.).

The poor control obtained with the poisoned bait was attributed to the fact that two applications per week are required to give satisfactory protection during periods of rapid plant growth and heavy infestations, such as were experienced during this experiment. The only material that injured the foliage was the poisoned bait, which caused slight crimping of the bud leaves during the latter part of the growing period.

EXPERIMENT IN 1951.—The 1951 experiment was similar to that carried out during 1950. The budworm infestation was heavy in both seasons, but noticeably less so during 1951. Dusts containing DDT, TDE, parathion, methyl parathion, and 4-methylumbelliferone 0,0-diethyl thiophosphate were tested. Finely ground tobacco dust was used as the diluent.

Twelve weekly applications were made during the growing season. The first nine applications at an average dosage of slightly less than 7 pounds per acre were directed toward the bud leaves. The last three applications at 10 pounds per acre were directed to the upper leaves and applied behind the operator. Y nozzles were used in the latter to aid in the distribution of the dusts.

After four applications it was evident that 4-methylumbelliferone 0,0-diethyl thiophosphate had given little control of the green peach aphid. Aphid populations were becoming so great on these plots as to endanger the precision of the experiment. This situation was remedied by the addition of 1 per cent of parathion to the dusts.

Of 7,650 leaves examined after each treatment, the percentages injured by budworms were as follows:

Parathion 1% plus—	
DDT 10%	0.7
TDE 10%	.8
Parathion 1% (alone)	17.7
Methyl parathion 2%	4.9
4-Methylumbelliferone 0,0-diethyl thiophosphate 2%	37.0

A satisfactory budworm control was obtained only with dusts containing 10 per cent of DDT or TDE, each with 1 per cent of parathion. None of the treatments caused any apparent injury to the tobacco foliage.

EXPERIMENT IN 1952.—The 1952 experiment was similar to those carried out in the previous seasons. Dusts containing DDT and TDE, each with parathion, and admixtures of them with zineb, were tested. The fungicide was included to meet the demand for an insecticide-zineb dust treatment for shade-grown tobacco. Methyl parathion plus DDT and CS-708 plus parathion were also tested. Finely ground tobacco dust was used as the diluent except in one dust, which was prepared with a calcined fuller's earth diluent.

The budworm infestation in 1952 was considerably lighter than in the two preceding seasons. Eleven weekly applications were made during the growing season. The average dosage was 9 pounds per acre.

Of the 1,050 leaves examined after each treatment, the percentages injured by budworms were as follows:

Parathion 1% plus—	
DDT 10%	1.2
DDT 10% and zineb 6.5%	1.3
TDE 10%	1.0
TDE 10% and zineb 5.6%—	
Tobacco dust diluent	1.3
Fuller's earth diluent	1.5
CS-708 1%	13.7
Methyl parathion 1% plus DDT 10%	1.5

A satisfactory budworm control was obtained only with dusts containing 10 per cent of DDT plus 1 per cent of parathion or methyl parathion, and 10 per cent of TDE plus 1 per cent of parathion. The addition of 6.5 per cent of zineb did not produce any apparent changes in the budworm control. CS-708 tested at 1 per cent plus 1 per cent of parathion was not effective. None of the treatments caused any apparent foliage injury.

SUMMARY.—Experiments were conducted at Quincy, Florida, during 1949–1952 on the control with insecticides of the tobacco budworm, *Heliothis virescens* (F.), on shade-grown tobacco. Weekly applications of dusts containing 10 per cent of DDT or TDE gave a more satisfactory control than the other materials tested, including CS-708, methoxychlor, and toxaphene. The addition of 1 per cent of parathion to these insecticides did not increase the budworm control appreciably. None of the dusts caused any apparent injury to the tobacco leaves.

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Garden Springtail Investigations[1]

LOYD L. STITT[2,3]

During recent years the garden springtail, *Bourletiella hortensis* (Fitch), has caused concern among growers of spinach, beans, cucumbers and squash. Damage is mainly to seedling plants. However, fresh market and processed spinach was also damaged.

Research work on garden springtail has been reported by Folsom (1933), Jewett (1937), Morrell & Lacroix (1939), and Gould (1944). No references to this pest were found in recent volumes of the JOUR-

[1] Scientific Paper No. 1237, Washington Agricultural Experiment Stations, Pullman. Project No. 1062.

[2] Formerly Associate Entomologist, Western Washington Experiment Station, Puyallup. Now employed by Velsicol Corporation, Chicago, Illinois.

[3] The author wishes to acknowledge the work by Vernon L. Miller, Associate Chemist, on the malathion residue analyses. Residue analyses were partially financed by a grant from American Cyanamid Company, New York.

NAL OF ECONOMIC ENTOMOLOGY, or in abstracts in the Review of Applied Entomology, during the period when many of the newer insecticides were available.

Prior to 1950 some injury to beans and cucumber seedlings had been observed and reported in western Washington. In 1950, one 5-acre field of pole beans had to be replanted due to springtail damage and poor cultural practices. During this same year springtail damage to spinach in some fields caused a reduction in grade. The increasing springtail injury warranted control tests. Preliminary insecticidal tests were conducted in 1950 and 1951.

Injury to the cotyledon leaves of beans and cucumbers is mainly a "pitting," as distinguished from the shot-hole effect of flea beetle injury. In some cases, however, feeding injury may become holes. These pits on beans and cucumbers vary in size but average 1/64-inch in diameter. When weather is warm, the first pair of true leaves develop rapidly, and there is then little plant mortality due to feeding of springtails.

Feeding injury on spinach is different from that on beans and squash. The spinach leaf is thin and feeding usually results in small holes instead of "pits," mainly on the small young leaves. Holes enlarge as the leaf develops and at harvest may be from $\frac{1}{4}$ to $\frac{3}{4}$-inch in diameter. These holes are undesirable since they increase field grading costs for fresh market and reduce grade when sold to processors.

A preliminary test using dusts of DDT, BHC, chlordane and methoxychlor was conducted for springtail control on beans. All materials gave fair immediate "knockdown", but control was unsatisfactory. Chlordane retarded the influx after the original knockdown.

Insecticide dusts used in 1951 were: rotenone, 1 per cent; DDT, 5 per cent; methoxychlor, 5 per cent; chlordane, 5 per cent; aldrin, 2.5 per cent; parathion, 1 per cent; and malathion, 4 per cent. Plot tests were made in a spinach field near Fife, Washington, on April 22 and 23. DDT, methoxychlor, chlordane, parathion and malathion were applied on April 22 at an estimated dosage of 25 pounds per acre. Rotenone was applied April 23 at 50 pounds per acre. These were unreplicated strip applications. Data were taken on May 1 by examining 10 plants in each treatment for number of springtails. The numbers recorded were: rotenone, 122; DDT, 9; methoxychlor, 6; chlordane, 17; malathion, 0; and parathion, 0.

On May 7, the rotenone-dusted area was used for a springtail control test using aldrin, chlordane, DDT, malathion, methoxychlor, and parathion. Dusts were used and applied at approximately 40 pounds per acre. Springtail numbers were determined on May 17 by taking 10 examinations per treatment. Due to the springtail habits, plant examination was not completely satisfactory.

Counts were obtained by a 15-second count of the number of springtails occurring on an $8\frac{1}{2}\times11$-inch white sheet of paper. The "sheet count" was more satisfactory than plant count. Number of springtails per treatment were: aldrin, 50; chlordane, 34; DDT, 67; malathion, 7; methoxychlor, 86; parathion, 1; and untreated check, 94.

Spinach samples were collected from the parathion plot on May 18, 11 days after dusting. Residue analyses resulted in 0.32 p.p.m. Spinach in other plots treated with malathion dust showed very rapid breakdown, according to residue analyses. Spinach treated on June 2 with 3.2 pounds actual malathion had an average in four samples of 167 p.p.m. Samples taken 24 hours later had a residue of 89 p.p.m. Samples collected 5 days after dusting had a residue of 0.35 p.p.m. In another residue study, 2.3 pounds actual malathion dust was applied on June 9. Residues from samples collected were: immediately after dusting, 101 p.p.m.; 24 hours after dusting, 49 p.p.m.; and 5 days after dusting, 0.4 p.p.m. Malathion dust applied at 2.3 pounds actual on June 13 had residues immediately after dusting and 24 hours later comparable to other data, but five days after dusting one analysis showed 10.4 p.p.m. with an average of 8.1 p.p.m.

RESULTS.—Parathion and malathion dusts gave good control of the garden springtail for 10 to 14 days. Dusts of aldrin, chlordane, DDT, methoxychlor and rotenone were unsatisfactory. Residue analyses for parathion 11 days after dusting showed 0.32 p.p.m. Malathion after 5 days was down to 0.4 p.p.m. in two tests, but in a third test was up in one analysis to 10.4 p.p.m.

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The Development of the Citrus Mealybug[1,2]

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Berlese (1893) observed four nymphal instars in the development of the *Pseudococcus citri* male and assumed that the female underwent the same number. It has since been demonstrated (Matheson 1907; Meyers 1932; James 1937; Pflugfelder 1939) that the female passes through only three nymphal instars. The weights of developing males and females, in addition to the number of days required for development, have been recorded in this study and are presented in graphic form in figure 1.

According to Berlese (1893), Matheson (1907), and MacGillivray (1921), the *Pseudococcus citri* male loses its mouth parts at the end of the first instar. Each investigator believed that the absence of mouth parts could be used as a means to distinguish the sex of mounted specimens of second instar nymphs. Pflugfelder (1939) noticed that the mouth parts were lost by the male at the end of the second instar rather than at the end of the first. This observation has been confirmed many times by the writer. Unfortunately, no satisfactory method has been found for separating the sexes of

[1] *Pseudococcus citri* (Risso). (HOMOPTERA, COCCIDAE).

[2] Contribution from the Entomological Laboratories. Part of a thesis submitted in partial fulfillment of the requirements for the degree Doctor of Philosophy.

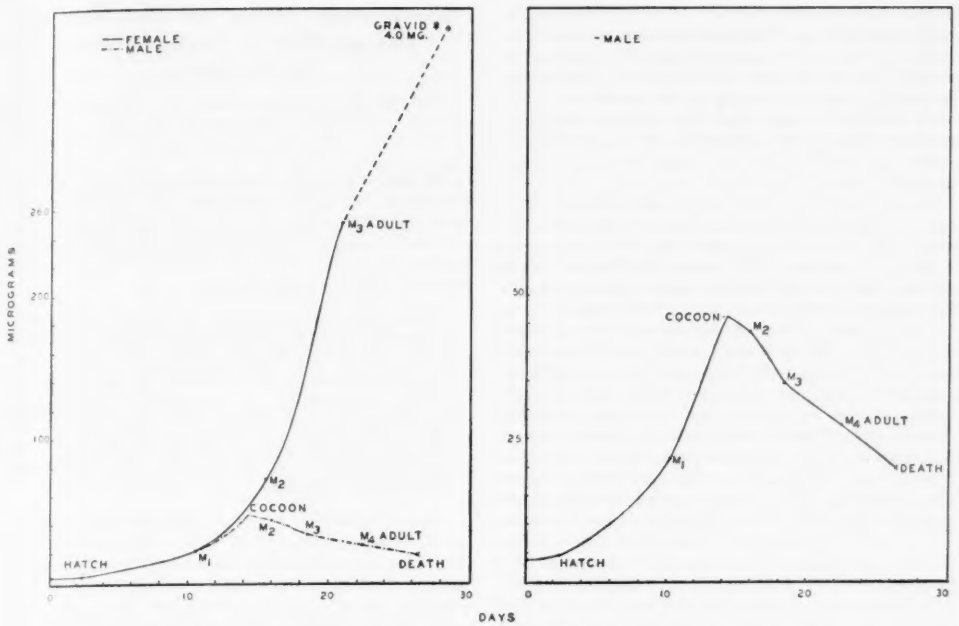

FIG. 1.—Changes in weights during the development of *Pseudococcus citri* males and females

mealybugs during the first two nymphal instars—prior to the time of formation of the cocoon by the male. Meyers (1932) claimed that the male was slightly longer than the female at the end of the first instar. This criterion is very difficult to use.

In order to carry out this study, a stock culture of mealybugs was maintained on Irish potato sprouts using the rearing method of Smith & Armitage (1920). Mealybug specimens were isolated for observation and weighing. All weights are expressed as averages and were obtained on a microanalytical balance. All rearing was carried out at room temperature.

Newly laid eggs, which averaged 3.7 μg., were collected from ovisacs and placed in a moist petri dish to hatch. Hatching normally required 2 to 3 days. At the time of hatching, the first instar nymphs averaged 4.5 μg. in weight. They were immediately placed on a potato sprout, the sprout directed into a glass test tube, and the mouth of the tube plugged with cotton. The cotton was fitted tightly around the sprout. At first the nymphs were very active, but eventually they began feeding and produced large quantities of honeydew.

Eight days after hatching from the eggs, the nymphs molted for the first time. The average weight was 21.6 μg. The second instar nymphs were then transferred to a new potato sprout, a procedure which was followed after each successive molt. Shortly after being transferred, the nymphs began to feed and to produce honeydew. They were soon covered with a fine, white, powdery wax.

Approximately 4 days after the first molt, the males formed a loosely spun white, cottony cocoon within which they remained for the rest of their immature life. At the time of formation of the cocoon, the males averaged 46.0 μg. in weight. By referring to figure 1 it can be seen that this was the greatest weight reached by the males at any time during the entire life cycle. Close examination of the nymphs revealed that the stylets were present within the crumena. The wings were visible as small bulbous protrusions, and the antennae were very much reduced.

Two days after formation of the cocoon, the males molted for the second time; the average weight was 43.0 μg. The stylets, no longer present on the nymphs, were found attached to the cast skins. In molting, the cast skins were shoved out through the posterior end of the cocoons. Although the males were capable of movement, normally they did not leave the cocoons until after reaching the adult stage. If a male nymph was removed from its cocoon, it formed another cocoon within a few hours.

Two to 3 days following the second molt, the males molted for the third time. The average weight was 34.3 μg. Near the end of this instar, which lasted for 4 days, the developing wings became much darker in color.

Four days after the third molt, the males molted for the fourth and final time to become adults. The average weight was 27.0 μg. Following the final molt, the males remained within the cocoons for 1 to 2 days during which time the anal appendages were extended and the wings and antennae became hardened.

The adult males normally lived from 4 to 7 days during which time they were very active. At the time of death the average weight was only 20.0 μg. The continuous loss of weight is easily understandable since the males were without mouth parts subsequent to the termination of the second instar.

The female nymphs completed the second instar in about 5 days. At the time of the second molt the average weight was 70.0 μg. Soon after molting, the females again began feeding and producing honeydew. Shortly thereafter their bodies were again covered with the fine, white, powdery wax.

Six days after the second molt, the females molted

for the third time to become adults. The average weight was 250 μg. The females were observed *in copula* with the adult males within a few hours after molting. Egg production started about 7 days after the mating and continued for 30 to 45 days, at which time the females died. The average weight of gravid females was 4.0 milligrams. Normally, the females continued to produce honeydew until near the end of their life.

Meyers (1932) reported parthenogenetic reproduction by *Pseudococcus citri* females, and asserted that he was able to rear three generations in the absence of the male. James (1937) repeated Meyers' work, but was unable to get similar results. James reported that unmated females did not produce ovisacs.

The findings of Meyers and James were checked by the writer. Third instar females were transferred to a new potato sprout which was then covered with a test tube. The tube was closed with cotton in such a manner that no males could enter nor could the females leave. The females molted and grew to normal size. No eggs were produced by any of them although one female did produce an empty ovisac. The production of an empty ovisac has been observed in the stock culture, therefore, this phenomenon cannot be exclusively associated with the restriction on mating. However, it is concluded that *Pseudococcus citri* females are not parthenogenetic.

A short time after the confined females had reached the adult stage, large numbers of adult males were found entrapped in the cotton plug of the test tube. None of the males were successful in penetrating the barrier. The females of many species of insects produce chemical compounds which serve to attract the opposite sex. This must have been the case with the female mealybugs since the males were congregated around the mouth of the test tube rather than in an area where they could see the females. The effectiveness of the attractant can be judged by the fact that the males were emerging from a stock culture which was 10 to 15 feet away from the confined females.

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Predaceous Mites of the Family Laelaptidae in North-Central Washington[1]

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Mites of the family Laelaptidae have gone almost unnoticed with little emphasis upon their importance. Modern spray practices are not conducive to survival of the species in orchards, although they are among the most active predators of spider mites known. Gilliatt (1935) stated,

> "This mite (*Seiulus pomi*) is probably the most important of all the predators attacking the European red mite in Nova Scotian orchards, not that it consumed more mites during the many periods under observation in comparison with other predators, but on account of its being active for the entire season from early spring before the red mite eggs hatch until well after all winter eggs have been deposited."

Newell (1941)[3] in his work with the pacific spider mite, *Tetranychus pacificus* McG., believed that were it not for the composition and heavy applications of sprays necessary to control codling moth in this district, the predaceous mite then known as *Seius pomi* would become the most important predator. H. H. J. Nesbitt (1951) reports,

> "As a result of four seasons of experimental and observational work in the main fruit growing areas of Canada, I am convinced that the complex of species loosely referred to as *Seius* (*Seiulus pomi*) is one of the most useful agents in the control of all tetranychid mites."

To find out what species of predaceous mites were present in this region, particularly in apple orchards, a collection was made of the predaceous species whenever they were found. They were not plentiful in the orchards, probably due to orchard sprays, but a few were found associated with spider mites. Occasional collections were made upon natural vegetation to compare with species found in orchards.

Of the numerous collections made during the growing seasons of 1951 and 1952, only *Typhlodromus longipilus* Nesbitt was found in apple orchards preying on tetranychid mites. This same species was found upon such wild plants as pin cherry, *Prunus emarginatus* and choke cherry, *Prunus virginiana* var. *demissa*. However, *Typhlodromus rhenanus* (Oudemans) was found quite abundantly on such wild plants as Alder (*Alnus*), Elderberry (*Sambuccus sp.*) and Mock Orange. (*Philadelphus gordonianus*). *T. rhenanus* is reported to be the principal apple spider mite predator at Summerland, British Columbia, but the author did not find any specimens on apple trees in this locality. One collection of *Phytoseius spoofi* (Oudemans) was found on elderberry, (*Sambuccus sp.*) near the Peshastin Creek area.

Typhlodromus longipilus is predaceous on all

[1] Scientific Paper No. 1254, Washington Agricultural Experiment Stations, Pullman, Project 849.

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[3] Newell, I. M. 1941. Bionomical studies of the Pacific mite, *Tetranychus pacificus* McG. (Acarina, Tetranychidae) in Central Washington. Unpublished thesis. Wash. State College Library Pullman ,Wash.

species of Tetranychidae of economic importance to orchards in North-central Washington. Eggs and nymphs of the spider mites are the more readily attacked. They are quite voracious, accounting for a good many eggs and nymphs of the Tetranychidae in their lifetime. The female of *T. longipilus* is from 0.31 mm. to 0.33 mm. in length and 0.2 to 0.22 mm. in width or approximately the same size as the female of the well-known European red mite. The body is oblong, and milky white to translucent, sometimes showing reddish through the body from the contents of the gut. The male is unknown.

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Mixtures of DDT and Other Insecticides for Control of Pink Bollworms and Boll Weevils in Southern Texas

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Large-scale experiments were conducted in southern Texas during the 1952 season to evaluate mixtures of DDT with other insecticides for control of the pink bollworm, *Pectinophora gossypiella* (Saund.) and the boll weevil, *Anthonomus grandis* Boh. An unusually high infestation of pink bollworms in the Lower Rio Grande Valley and Coastal Bend areas afforded an excellent opportunity to obtain needed information as to the increase in cotton yield that might be obtained from control of this insect with insecticides. Although the experiments were designed primarily against the pink bollworm, insecticides for boll weevil control were incorporated when damaging infestations appeared. Control of both boll weevils and pink bollworms were compared with that of boll weevils alone. Of the several experiments conducted, five representative ones will be discussed in this report. Experiments Nos. 1 to 4 were conducted in Cameron County, and No. 5 in Calhoun County.

PROCEDURE AND MATERIALS USED.—Approximately 120 acres were involved in these experiments, including 110 that were treated and 10 used as untreated checks. The untreated plots ranged in size from 1 to 4 acres, and the treated ones from 1 to 10 acres, except the single treated plot in experiment No. 5 which was 60 acres. There was only one replicate of treatments in each experiment.

DDT mixtures containg dieldrin, EPN, BHC, or toxaphene were used on plots treated for control of both pink bollworms and boll weevils. Dieldrin, which is not effective against the pink bollworm, was used on plots treated for control of boll weevil alone. Insecticides were also applied on the various plots for control of aphids and spider mites when needed. All the insecticides were applied as sprays, except a DDT-toxaphene dust formulation used in one experiment and a dust containing BHC, DDT, and sulfur in another. Except in a few cases when irrigations or rain necessitated airplane application, the insecticides were applied with tractor-type machines. The sprayer was equipped with three nozzles per row, which delivered about 5 gallons of emulsion per acre, and the duster with one nozzle per row. Applications for pink bollworm control were made at 7-day intervals, except when boll weevil infestation warranted shorter intervals between applications.

DISCUSSION AND RESULTS.—A summary of infestation and cotton-yield records in the various treatments for the five experiments are shown in table 1.

In experiment No. 1 a plot was included for boll weevil control, one for boll weevil plus pink bollworm control, and an untreated plot. The cotton matured early in this experiment, and poison applications were begun a little too late for optimal control of the prevailing high infestation of pink bollworms. The initial pink bollworm infestation was extremely high as shown by early-bloom infestation counts. Nine applications of DDT were made for control of this insect, while dieldrin was needed for boll weevil control only during the period of the last four applications. A low yield of 133 pounds of seed cotton per acre was obtained on the untreated plot. On the treated area there was an increase of 37 pounds for boll weevil treatment alone and 710 for the control of both insects, or a difference of 673 pounds for pink bollworm control.

Experiment No. 2 was a repetition of the treatments in experiment No. 1. The cotton was far advanced and both the boll weevils and pink bollworms were well established at the time treatments were begun. Thirteen applications were made of dieldrin alone and mixed with DDT. Timely rains stimulated new growth and the plants virtually produced a second crop where these insects were controlled. An increase of 471 pounds of seed cotton per acre was obtained from dieldrin alone and a further increase of 1069 pounds when DDT was added. Boll weevil infestation was lower in the plot treated with the DDT-dieldrin mixture than with dieldrin alone. Consequently, the high increase in yield from the mixture was not due entirely to pink bollworm control, but in part to better boll weevil control.

The insecticides used in experiment No. 3 were DDT plus dieldrin or EPN, and dieldrin alone. Eight applications were made against pink bollworms and 4 to 5 against boll weevils. The two mixtures were about equally effective in controlling the boll weevil. The addition of EPN to DDT increased pink bollworm control, and the addition of dieldrin to DDT again gave a higher boll weevil control than dieldrin alone. Chiefly owing to pink bollworm control the former mixture increased seed cotton yield 929 pounds per acre and the latter 478 pounds over that of dieldrin alone.

Experiment No. 4 was brought underway at about the time boll weevils began to migrate in considerable numbers, and although the initial infestation was low, materials for control of this insect were included in all treatments. Weekly applications held the weevil population below damaging numbers until near the end of the experiment. Eight applications were made of the various insecticides, which included sprays containing DDT plus dieldrin or EPN and a dust containing BHC, DDT, and sulfur (2–10–40). EPN at 0.5 pound gave about the same

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Table 1.—Infestation and cotton-yield records for insecticide experiments in southern Texas, 1952.

Insecticide (Pounds per Acre)	Number of Applications	Per Cent of Squares Punctured by Boll Weevil	Pink Bollworm		Pounds of Seed Cotton per Acre		
			Number of Larvae per Boll, Seasonal Average	Per Cent Reduction in Larval Population	Yield	Gain Over Dieldrin Treated Plots	Gain Over Untreated Check
Experiment No. 1 (sprays):							
Dieldrin 0.375	4	39	17.9	—	170	—	37
DDT 2+dieldrin 0.375	9[1]	32	2.7	83.8	843	673	710
Untreated check	—	38	16.8	—	133	—	—
Experiment No. 2 (sprays):							
Dieldrin 0.45	13	55.0	6.3	7.2	1276	—	471
DDT 1.63+dieldrin 0.45	13	44.8	0.8	88.2	2345	1069	1540
Untreated check	—	80.1	6.8	—	805	—	—
Experiment No. 3 (sprays):							
Dieldrin 0.375	5	41	7.6	—	1325	—	—
DDT 2+dieldrin 0.375	8[1]	35	1.6	79.3	1803	478	—
DDT 2+EPN 0.5	8[1]	35	0.9	89.1	2254	929	—
Experiment No. 4							
DDT 1.5+dieldrin 0.25 (spray)	8	15	3.6	73.0	1045	—	780
DDT 1.0+EPN 0.5 (spray)	8	16	1.2	90.8	1370	—	1105
DDT 2+BHC, gamma 0.4 (2-10-40 dust)	8	30	4.0	70.4	800	—	553
Untreated check	—	47	13.4	—	265	—	—
Experiment No. 5 (dust)							
DDT 1.5+toxaphene 3	7	7	2.7	87.0	740	—	740
Untreated check	—	53	21.0	—	None	—	—

[1] Only last 4 or 5 applications needed for boll weevil control.

boll weevil control as dieldrin at 0.25 pound, and both were more effective than the 2–10–40 dust. Again the addition of EPN to DDT increased pink bollworm control and showed the highest increase in cotton yield. The per acre increases in seed cotton yield from the various treatments were as follows: 2–20–40 dust, 533 pounds; DDT-dieldrin spray, 780 pounds; DDT-EPN spray, 1105 pounds. These increases were due mainly to pink bollworm control.

The field used for experiment No. 5 was planted the middle of April. Largely because of cotton fleahopper damage, the plants had set few bolls when the experiment was begun the first of August. At that time the boll weevils and pink bollworms had begun to migrate into the field. Only 70 days remained in which to complete and harvest the crop by the plow-up deadline on October 10. A dust containing 7.5 per cent of DDT and 15 per cent of toxaphene was applied at the rate of 20 pounds per acre every 5 days except when rain interfered. Seven applications were made between August 1 and September 4. The amount of cotton harvested on the treated portion of the field was considerably decreased from the potential yield, because of the compulsory early plow-up date. The bolls produced on the untreated area were so severely damaged by pink bollworms that no cotton was harvested on the check plot. A yield of 740 pounds of machine-picked seed cotton was obtained from the treated area.

SUMMARY.—Five large-scale insecticide experiments were conducted in southern Texas in 1952 to evaluate mixtures of DDT with other insecticides for the control of the pink bollworm, *Pectinophora gossypiella* (Saund.), and the boll weevil, *Anthonomous grandis* Boh. The insecticides used with DDT were EPN, dieldrin, BHC, or toxaphene. All the mixtures increased the yield of seed cotton, the higher increases resulting from control of the pink bollworm. The addition of dieldrin to DDT caused considerable increase in boll weevil control over that obtained with dieldrin alone. The addition of EPN to DDT increased pink bollworm control and gave satisfactory control of the boll weevil.

Variations in Hatching of Ova in Successive Lots Obtained from Colonized *Anopheles quadrimaculatus* Say

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The data on which these observations are based were collected in the course of a study on the biotic potential of *Anopheles quadrimaculatus* Say (Bellamy 1950). The purpose of this note is to record variation in hatching of ova among successive lots oviposited by female *A. quadrimaculatus* isolated from an established laboratory colony. Procedures were described completely in the article previously mentioned (Bellamy 1950).

Anopheles quadrimaculatus females used in this study were obtained from a colony of the Q_1 strain maintained in the National Institutes of Health laboratory at Milledgeville, Georgia. Newly emerged

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Table 1.—**Number of ova and per cent that hatched in successive lots from isolated *Anopheles quadrimaculatus* females in cases where rates of hatching were consistently high.**

Lot No.	Specimen Number									
	142	143	144	147	253	256	258	260	261	262
	Ova Produced									
1	59(95)[1]	212(93)	152(97)	170(98)	222(87)	186(77)	154(97)	261(98)	224(94)	240(94)
2	130(90)	211(98)	149(99)	167(97)	184(85)	30(63)	248(94)	260(83)	227(95)	226(94)
3	11(100)	211(97)	109(97)	165(95)	218(98)	154(100)	226(95)	234(97)	198(95)	226(94)
4	180(93)	189(96)	133(77)	156(93)	226(96)	164(98)	166(95)	248(95)	130(98)	180(95)
5	181(98)	176(94)	111(97)		213(96)	172(99)	147(86)	190(93)		220(99)
6	185(96)	144(98)	92(89)		142(99)	160(95)	88(98)	110(97)		138(96)
7			65(92)		147(84)	86(85)	156(94)	110(92)		96(77)
8							129(85)			
9							97(95)			
10							110(84)			
All	746(95)	1,191(92)	811(93)	658(96)	1,352(93)	952(92)	1,521(93)	1,413(93)	779(95)	1,326(94)

[1] Numbers in parenthesis indicate per cent hatched.

mosquitoes were placed in cages and after 4 days allowed to feed on a rabbit. Engorged females were removed and isolated individually in lantern chimneys over bowls containing tap water. Daily examinations were made of each specimen, ova were counted and placed in bowls to observe hatching, and all mosquitoes were given an opportunity daily to feed on human blood. Four or more lots of ova were obtained from 17 of 26 females isolated. Ten specimens oviposited regularly at 3 to 5-day intervals following each successive blood meal and produced ova that exhibited a high rate of hatching. The number of ova obtained from these specimens and per cent of ova that hatched are shown in table 1. Oviposition of the remaining 7 specimens was similar except that the rate of hatching decreased in successive ovipositions (table 2).

These data confirm the general impression that sufficient sperm can be retained by the female to fertilize ova produced throughout the life span. Reduction in the proportion of ova that hatched in the second series suggests that insemination was insufficient or that the sperm or ova had become inviable. Since *Anopheles quadrimaculatus* probably mate repeatedly, an experiment was devised to determine if repeated insemination would increase the proportion of ova that hatched. Twenty-five female mosquitoes were removed from a colony cage containing approximately equal numbers of males and females after they had taken their first blood meal 4 days after emergence. In another cage, 25 females and 50 males were isolated. Females in the first cage had opportunity to mate during the first 4 days after emergence; those in the second cage could mate repeatedly. Mating was observed frequently in the second cage. During a period of 28 days, 12,025 ova were obtained from the first cage and 87 per cent of the ova hatched. From the second cage, 17,961 ova were obtained in 42 days and 68 per cent of the ova hatched. This suggests that the factors other than depletion of the supply of viable sperm may be responsible for decrease in the hatching rate. This is further attested by the gradual reduction and variation in rate of hatching. Depletion of the viable sperm supply would effect an abrupt termination of hatching.

It is concluded, accordingly, that reduction in the rate of hatching is probably due to production of nonviable ova.

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Table 2.—**Number of ova and per cent that hatched in successive lots from isolated *Anopheles quadrimaculatus* females in cases where rates of hatching decreased.**

Lot No.	Specimen Number						
	124	141	046	148	255	257	259
1	155(96)[1]	163(100)	60(98)	166(98)	183(91)	160(93)	147(99)
2	138(91)	171(95)	57(70)	140(89)	174(85)	121(93)	161(87)
3	123(94)	146(9)	96(21)	123(85)	168(90)	138(94)	157(96)
4	109(30)	123(100)	82(52)	161(58)	134(88)	109(83)	155(84)
5	102(2)	93(95)	67(43)	125(7)	113(85)	93(65)	110(83)
6	81(0)	43(74)		94(0)	100(78)		95(78)
7				99(1)	67(63)		41(44)
8				57(0)			61(46)
9				63(0)			52(0)
All	707(60)	739(96)	362(53)	1,028(48)	939(85)	621(87)	979(79)

[1] Numbers in parenthesis indicate per cent hatched.

Drosophila, a Sensitive Insect, for the Microbioassay of Insecticide Residues[1]

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In the bioassay of microquantities of insecticides in plant and animal tissues, the house fly and several species of mosquito larvae are commonly used. Mosquito larvae are more sensitive than house flies in detecting minute quantities of insecticides. However, the greater variation in results, the higher natural mortality in cultures, and the time-consuming work in carrying out experiments make mosquito larvae less desirable as test insects for routine bioassay of insecticide residues.

For a long time there has been a search for an insect which is as sensitive as mosquito larvae but which can be handled as easily as the house fly. After testing a number of species of insects it was found that pomace flies, *Drosophila melanogaster* Meig., which are also known as vinegar flies or fruit flies, can serve the purpose. One wild strain and two laboratory strains of *D. melanogaster* have been tested against several insecticides. No appreciable difference in susceptibility was found. Only one laboratory strain[3] is used for the present study.

Pomace flies are reared on canned pumpkin, as described by Bartlett (1951). Only 1-day old flies are used for tests.

METHOD 1.—*Exposing Pomace Flies to Macerated Tissues.*—Results obtained in the determination of dieldrin in milk by feeding house flies with milk (Sun & Sun 1952a) led to the development of the method of analyzing plant tissues described here. This method consists of exposing adult pomace flies to macerated plant tissues. To evaluate the insecticidal content of a sample, mortalities resulting from exposure to treated plant tissues are compared with mortalities resulting from exposure to standards containing known amounts of the same insecticide.

The procedure for preparing plant tissues for tests consists essentially of macerating the tissues in a high speed blender[4] until a uniform slurry, similar to that of baby food, is obtained. If necessary, water may be added to facilitate maceration. The concentration of the insecticide-acetone solution added to the macerated, untreated tissue for making standards should be such that not more than 0.5 ml. of acetone solution is added to 25 gms. of sample. The same amount of acetone should be added to treated samples to compensate for any possible effect on the flies.

For the routine bioassay of insecticide residues below a certain level it is only necessary to compare the mortality of flies exposed to treated samples to the mortality in the standard at that level. About 20 gms (one tablespoon) of the macerated tissue are placed into each of six 4-oz. wide-mouth glass jars. Fifty 1-day old carbon dioxide-anesthetized adult pomace flies are counted into a small glass cup which in turn is placed in the jar with the plant tissue. Thus the flies will not adhere to the macerated tissue after they revive from the anesthesia. Then each jar is covered with a piece of tissue paper held in place by a rubber band. The jars are held at $27 \pm 1°$ C. Mortality counts (both dead and moribund) are made and recorded 18 to 48 hours later when the mortality in the standards ranges from 30 to 80 per cent. The ranking method (Wilcoxon 1946) may be used to determine the significance of difference between mortalities in the standard and treated samples.

Table 1.—Sensitivity of house flies, yellow-fever mosquito larvae, and pomace flies to microquantities of several toxicants.

Toxicants	Minimum Detectable Amounts of Toxicants, Micrograms per Container; 24-Hour Count		
	House Flies[1] (0.2 of LD 50)	Mosquito Larvae[2] (Breaking Point Range)	Pomace Flies[1] (0.2 of LD 50)
BHC (gamma isomer)	0.80	0.12	0.09
Aldrin	0.23	0.04	0.05
Dieldrin	0.15	0.12	0.04
DDT	12.0	0.47	2.0

[1] Original (Method 2).
[2] Approximate values calculated from table 2 of Hartzell & Storrs (1950).

To evaluate higher insecticide residues a definite value may be required. Then these samples may be prepared as above, except the standards should contain three or four levels of the same toxicant to be analyzed. The amount of insecticide in the treated sample is determined by comparing the percentage mortality obtained from exposure to treated plant tissues to the standard reference curve plotted in log-probit scales. The procedures and precautions described by Sun & Sun (1952b) may also be used in this experiment. The result obtained in the present method is expressed in p.p.m. (parts per million) rather than micrograms per jar.

METHOD 2.—*Exposing Pomace Flies to Dry Residues.*—When pomace flies are used for the bioassay of dry residues deposited from the evaporation of plant or animal tissue extracts, the same methods described by Sun & Sun (1952b) for house flies can be used. Minor differences are that the extract is deposited on the bottom of a 4-oz. wide-mouth jar, pumpkin serves as the food for pomace flies, and each jar is covered with a piece of tissue paper. Generally, pomace flies are 4 to 9 times more sensitive to some insecticides than house flies (Table 1). Since pomace flies are more sensitive to toxicants, they are more susceptible to insecticidal contamination and more sensitive to natural toxicants extracted from plant or animal tissues. It is suggested that the pomace flies should only be used to determine minute quantities of a toxicant which cannot be detected by house flies.

RESULTS.—By exposing macerated tissues (Method 1) to pomace flies as low as 0.1 p.p.m. of aldrin or dieldrin can be detected in many fresh and canned fruits and vegetables, such as potato, peas, spinach, etc. The residue method (Method 2) is used

[1] Presented at the annual meeting of the International Great Plains Conference of Entomologists at Waskesiu, Canada, August 14–16, 1952.
[2] Transferred to Julius Hyman & Company Division of Shell Chemical Corporation.
[3] Strain 6a, obtained from Genetics Division, University of California.
[4] *Osterizer*—Model No. 18; 18,000 to 20,000 r.p.m.; obtainable at scientific equipment or electrical appliance companies.

in cases where an extraction is necessary either because the particular tissue cannot be analyzed by method 1 or because of the small sample size. Method 2 has been successfully used for determining the amount of aldrin and dieldrin in the extracts of brain, liver, kidney, muscle and fat obtained from rats used in toxicological studies. As low as 0.05 microgram of aldrin or dieldrin per test jar can be detected by this method. The sensitivity of methods 1 and 2 can be calculated by the equations devised for the feeding method (Sun & Sun 1952a) and the residue method (Sun & Sun 1952b) respectively.

Since the sensitivity of a microbioassay method expressed in p.p.m. of a toxicant in either a sample or a test solution varies with the sample weight and other factors, comparison of the sensitivity of various test insects is not possible if the tests are not conducted in the same way. To compare the sensitivity of test insects, it is easier to find the differences on the basis of the minimum detectable quantity of the same toxicant per test container rather than in terms of p.p.m. In table 1, the minimum detectable amount of an insecticide for yellow-fever mosquito larvae, *Aedes aegypti* (L.), is based on the breaking point range (Hartzell & Storrs 1950) and that for the house flies or pomace flies is based on the 0.2 of LD 50 (Sun & Sun 1952b). According to these methods of bioassaying insecticide residues with the above three species of insects, pomace flies are about as sensitive as mosquito larvae and both pomace flies and mosquito larvae are more sensitive than house flies, when the results are expressed as the minimum detectable amount. However, when pomace flies were used for detecting toxicants in milk by the feeding method (Sun & Sun 1952a), they were far less sensitive than house flies in detecting aldrin, dieldrin, DDT and gamma isomer of BHC.

SUMMARY.—It has been found that pomace flies, *Drosophila melanogaster* Meig., are more sensitive than house flies and about as sensitive as yellow-fever mosquito larvae in the microbioassay of insecticide residues. By exposing pomace flies to macerated tissues, 0.1 p.p.m. of aldrin or dieldrin can be detected in many fruits and vegetables. By using the residue method of bioassay, as low as 0.05 microgram of aldrin or dieldrin can be detected in each test container.

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Life History and Control of *Apion longirostre* Olivier

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This insect, of European origin and described by Olivier (1807), has now become widely distributed in the United States. The U. S. National Museum has specimens collected from Lorain County, Ohio, in July, 1947; and from White County, Arkansas, in May, 1948. Sleeper (1953), after examination of the Dury collection, noted specimens from Georgia collected in 1914 and 1922. He (unpublished) indicates the probable distribution at present as being from the area bounded by the Hudson River in New York State to Des Moines, Iowa, south to St. Louis, Missouri, east to Philadelphia, Pennsylvania, and north to the Hudson River. Further observations will be necessary to more accurately determine the infested localities.

Wagner (1909) briefly reported on some habits of the weevil. Our observations indicate that the hollyhock weevil, *Apion longirostre*, feeds only on hollyhock, none being found on closely related plants. Damage is caused by the adults feeding on the leaves and buds, and the larvae completely destroying the seed embryo. Adult feeding on the leaves has the appearance of small round holes.

Measurements of adults of both sexes showed the males to average 5 mm. and the females 6 mm. in length. The length of the rostrum of the females is approximately twice that of the males, while the body width of both sexes is approximately 1 mm. Coloration of the rostrum, eggs, antennae, and body is black, with the elytra and ventral surfaces of the thorax and abdomen covered with gray, hair-like pubescence. The legs are light tan with black tarsi. (Fig. 1).

There is evidence that the overwintering stage is adult. Egg deposition begins with the formation of flower buds on hollyhocks in June. The female drills through the calyx and petals of the buds with her long rostrum and then oviposits in the cavity. While ovipositing, she is usually surrounded by several males. The eggs are creamy white, oval-shaped and approximately 0.1 mm. by 0.5 mm. in size. Inside the flower buds they are difficult to observe because of similarity in appearance to the stamens. The number of eggs laid by a female was not determined, however 20 adults were dissected and each contained from 10 to 17 eggs.

Hatching occurs in 3 or more days and the small white, legless larva (Fig. 2) crawls down through the stamen area into the placental tissue of the bud and devours the seed embryo. Pupation takes place in the space occupied by the seed embryo. The exact number of larval instars has not been determined. Before pupation the larva chews a hole through the outer surface of the seed coat. This hole is covered with a white secretion and the adult emerges through it in early August. Newly emerged adults are seldom seen outside the seed pods and appear to feed on the dry seeds. Observations indicated that only one generation developed during the year.

The relative toxicity of various concentrations of aldrin, chlordane, dieldrin, DDT, heptachlor and lindane was determined by exposing field-collected adult weevils to filter papers dipped in acetone solutions of the toxicants. The treated papers were placed on the bottom of plastic utility dishes with screen covers. Two replicates of 10 insects were used

FIG. 1.—Female and male adults of *Apion longirostre*, and pupa in a hollyhock seed. (Photo by Dept. of Photography, Ohio State University.)

for each dosage level. All compounds gave 100 per cent mortality in 24 hours at concentrations of 1.0 and 0.1 per cent. The results at concentrations of 0.01 and 0.001 per cent are tabulated below.

	Concentration			
	0.01 Per Cent		0.001 Per Cent	
	Average Mortality (Per Cent)			
Compound	24 Hrs.	48 Hrs.	24 Hrs.	48 Hrs.
Aldrin	100	100	0	5
Chlordane	40	100	0	0
DDT	65	100	0	0
Dieldrin	90	100	0	20
Heptachlor	35	100	0	5
Lindane	100	100	5	40
Check	5	10	0	0

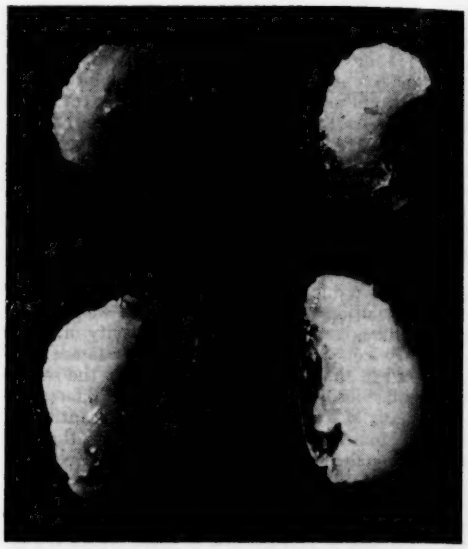

FIG. 2.—Larvae (top) and pupae (bottom) of *Apion longirostre*. (Magnification 8×.) Photo by Ohio State University Department of Photography.

These data indicate that all compounds were highly toxic at concentrations of 0.01 per cent or higher, but lindane and dieldrin were the most toxic at 0.001 per cent concentration. From these results it is concluded that satisfactory control of the hollyhock weevil can be achieved by spraying with any of the compounds as emulsions or wettable powders at a concentration of 0.1 per cent. Dust formulations should also be effective at standard concentrations. Applications are recommended in the spring when the adults are feeding on the leaves and before the flower buds become well developed. Cutting and burning the stalk with infested seed pods in late July or early August would destroy many larvae and pupae.

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Preliminary Tests with Carbon Monoxide against Several Insects

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The high toxicity of carbon monoxide gas to warm-blooded animals (U. S. Public Health Service 1941) frequently brings up the question of its efficiency against insects. Wille (1929) reported a mixture of carbon monoxide and hydrogen sulfide to be effec-

[1] The writer expresses his appreciation to E. F. Knipling for providing the body louse eggs, and E. R. McGovran and P. G. Piquett for the cockroaches for these tests.

tive against leaf-cutting ants in the soil. Peters (1936) indicated that carbon monoxide alone or in mixture with other toxic gases was used to kill rats and plague fleas on ships. Bodine (1937) reported that high concentrations of carbon monoxide depressed the oxygen consumption of grasshopper embryos. The preliminary fumigation tests reported herein were made in 1943 to determine the efficiency of carbon monoxide against several insects of military interest at that time—bed bugs (*Cimex lectularius* L.), body lice (*Pediculus humanus humanus* L.), confused flour beetles (*Tribolium confusum* Duv.), American cockroaches (*Periplaneta americana* (L.)), and German cockroaches (*Blattella germanica* (L.)).

Carbon monoxide was generated in a 500-ml. flask by the reaction of formic acid (99–100 per cent) with concentrated sulfuric acid by a procedure similar to that described by Sayers *et al.* (1922), and then passed through a soda-lime tube to dry it and to remove any carbon dioxide or acid vapor. Sayers *et al.* obtained gas of approximately 99-per cent purity by this method. No quantitative test on carbon monoxide concentration was made, but a qualitative test with palladium chloride (Berger & Schrenk 1938) confirmed the presence of carbon monoxide.

A 12-liter glass flask, used as a fumigation chamber in a technique similar to that described (Richardson & Casanges 1942), was first evacuated by means of suction to an absolute pressure of approximately 570 mm. of mercury. The flask was then attached to the generator line and the carbon monoxide drawn in slowly to atmospheric pressure (760 mm.). This gave a calculated concentration of carbon monoxide of about 25 per cent by volume (approximately 285 mg. per liter of air, or 18 pounds of carbon monoxide per 1,000 cubic feet). The exhaust from a gasoline engine averages near 7 per cent of carbon monoxide and producer's gas from coke contains near 25 per cent (Sayers & Yant 1923).

Confused flour beetles were exposed in cages, body lice eggs on pieces of cloth, and bed bugs in small glass beakers, and cockroaches were allowed to run free inside the fumigation chamber. The insects were exposed to the gas for 5 or 24 hours at a temperature of 77±1° F. and relative humidity of 30–50 per cent, and then held at 80°–85° for 4 to 28 days before they were examined for mortality. Untreated check insects were kept for each treatment.

The results, given in table 1, indicate that even with a 24-hour exposure carbon monoxide at 25 per cent concentration had little toxicity to any of these insects.

Carbon monoxide is classed by Henderson & Haggard (1927) as a chemical asphyxiant against man. It combines with the hemoglobin in red blood cells to prevent carriage of oxygen to the tissues. Its low toxicity to insects may be due to their lack of hemoglobin, as indicated by Cotton (1941). Of course the ideal insect fumigant would be just the opposite of carbon monoxide—*i.e.*, have a high toxicity to insects but little or no toxicity to man.

Table 1.—Toxicity of carbon monoxide as a fumigant for various insects, Beltsville, Md., 1943. Average of 2 tests.

Insect	5-Hour Exposure		24-Hour Exposure	
	Number of Insects Tested	Per Cent Mortality	Number of Insects Tested	Per Cent Mortality
Bed bugs:				
Adults	24	0	77	5.7
Nymphs	145	2.4	158	24.7
Eggs	8	12.5	—	—
Confused flour beetles (adults)	88	9.1	85	43.6[1]
Body lice (eggs)	616	22.1[2]	476	8.6
American cockroaches (adults and nymphs)	13	23.1[3]	13	15.4[3]
German cockroaches (adults and nymphs)	17	23.6[3]	19	5.3

[1] In one test kill was 0 after 5 days but 100 per cent in 28 days. A repeat test gave only 9.3 per cent kill in 15 days.
[2] Net mortality was 0 as untreated check mortality exceeded this. Repeat check mortality was 18 per cent.
[3] Excess of white oil present in dishes to prevent escape was apparently cause of some of this mortality.

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Residues of Malathion on Greenhouse Lettuce and Tomatoes and on Green Onions

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A previous paper (Smith *et al.* 1952) reported on residues found on greenhouse vegetables following applications of parathion, sulfotepp, and DDT, in aerosols. The present paper includes the results of similar tests with aerosols containing malathion. Data are also included on the residues found on above-ground portions of green onions grown from

sets in small field plots that had been dusted or sprayed with malathion.

METHODS.—In the greenhouse experiments aerosols containing 10 or 15 per cent of malathion in methyl chloride were applied at rates to give 1 or 1.5 grams, respectively, per 1000 cubic feet. The aerosols were applied near sundown, and the greenhouses were left closed for an exposure period of 12 to 15 hours at 70° F.

For each sample of tomatoes 10 fruits of similar size and maturity were collected from 20 clusters located in various parts of the greenhouse. Lettuce plants selected for uniformity were growing in pots for one experiment and spaced in beds as for a commercial crop in the two later experiments.

For the experiment on green onions, sets of variety Ebenezer were planted on March 10 in rows 15 inches apart. A 4-per cent malathion dust was applied at the rate of 30 pounds per acre. Sprays containing a 25-per cent malathion wettable powder or a 50-per cent emulsifiable concentrate were applied at the rate of 100 gallons per acre. Application rates of malathion per acre were 1.2, 0.5, and 1.0 pound, respectively, for the dust, wettable powder, and emulsifiable preparations. Samples of five onion plants selected for uniformity in size were collected from each plot at intervals and the above-ground portions were used for analysis.

All samples were analyzed on the day collected, and the results were corrected for the determination on the untreated material. The vegetable samples were extracted with redistilled carbon tetrachloride without either cutting up or washing, and the analyses were made by the colorimetric method developed by the American Cyanamid Company (unpublished).

RESIDUES ON LETTUCE.—Residues from similar dosages of malathion and parathion in 10-per cent aerosols were compared by treating potted lettuce plants in separate greenhouse units.

The original deposit of parathion and the rate of decline over a period of 12 to 13 days on mature plants (Table 1) were in close agreement with those obtained in previous studies (Smith *et al.* 1952, Table 6). One day after treatment the residues of malathion were less than half those of parathion, and the decline was more rapid. There was less than 1 p.p.m. after 6 days, whereas the parathion residue was in excess of 2 p.p.m. after 12 days.

In a second experiment on immature and mature leaf lettuce with malathion in a 15-per cent aerosol (Table 2), the residues were more than 50 per cent greater and persisted for a longer time than those from the 10-per cent aerosol (Table 1). The greater residue from the 15-per cent aerosol may de due to the larger particle size and hence greater deposit on the foliage, which is characteristic of the more concentrated aerosols (Fulton *et al.* 1949). However, these residues disappeared more rapidly than did parathion residues in earlier work.

Table 1.—Malathion and parathion residues on potted lettuce from 10-per cent aerosols.

INTERVAL BETWEEN APPLICATION AND HARVEST	MALATHION	PARATHION
	p.p.m.	*p.p.m.*
1 hour	—[1]	38.0
1 day	9.75	21.8
3	3.46	8.2
6	0.85	5.6
9	.46	4.5
12	0	2.4

[1] Sample lost during analysis.

Table 2.—Malathion residues on commercial lettuce from 15-per cent aerosols.

INTERVAL BETWEEN APPLICATION AND HARVEST	IMMATURE LETTUCE		MATURE LETTUCE	
	Sample weight	Residue	Sample Weight	Residue
	Ounces	*p.p.m.*	*Ounces*	*p.p.m.*
1 hour	14.5	21.9	24	21.2
1 day	15	15.3	29	15.9
3	20	20.5	30.5	12.4
6	23.5	3.6	34	3.8
9	28	.4	40	.3
13	32	0	46	0

In the first experiment the potted lettuce plants grew very little, so that the decline in malathion residues was due to chemical changes and volatilization rather than to increase in weight. In the second experiment weight increases played a smaller part in decline of residues than did the chemical changes and volatilization.

RESIDUES ON TOMATO.—An experiment with a 10-per cent malathion aerosol on tomatoes showed original deposits of 0.3 to 0.4 p.p.m. on the fruits and their complete disappearance by the third day (Table 3). In a parallel experiment with a 15-per cent aerosol a deposit near 1 p.p.m. and its persistence for a week are indicated. The greater deposit from the more concentrated aerosol was similar to the results with lettuce. Compared with the deposits from parathion aerosols (Smith *et al.* 1952, Table 6), those from malathion aerosols are lighter and disappear more rapidly.

Table 3.—Malathion residues on tomato fruits from 15- and 10-per cent aerosols.

INTERVAL BETWEEN APPLICATION AND HARVEST	15-PER CENT AEROSOL	10-PER CENT AEROSOL
	p.p.m.	*p.p.m.*
1 hour	1.05	0.31–0.41
1 day	.60	.90– .32
3	.26	0
6	.14	0
9	.02	0
12	0	0

RESIDUES ON GREEN ONIONS.—In the experiment on green onions (Table 4), malathion residues appeared to be lowest from dusts. Of the two sprays the wettable powder gave greater residues than did the emulsion. The residues were not proportional to the quantity of insecticide applied. A heavy rain on the second day after the first treatment apparently washed off or hydrolyzed the malathion and no residues were found on the third day. After the second treatment the plants were exposed to dews but no rain, and the residues declined rapidly after the first day and practically disappeared in a week.

Table 4.—**Malathion residues on the foliage of green onions following the application of malathion in a dust, an emulsion, and a wettable powder spray.**

Date Treated	Interval Between Application and Harvest	Dust	Emulsion Spray	Wettable Powder Spray
		p.p.m.	*p.p.m.*	*p.p.m.*
May 11	1 day	3.7	7.15	17.0
	3	0	0	0
June 2	1 hour	3.6	10.56	18.76
	1 day	4.08	4.0	13.56
	2	2.46	1.68	3.27
	3	1.60	1.02	2.10
	6	0.44	.53	.85
	7	0	.22	.22

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A Preliminary Report on the Colorimetric Detection of Dieldrin[1]

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Dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-*endo-exo*-dimethanonaphthalene) is an extremely efficient insecticide against many insects. Chemically, dieldrin is surprisingly inert, and the fact that its characteristic epoxide moiety can be cleanly opened only with difficulty has hindered the development of a color test suitable for the quantitative determination of dieldrin in technical grade materials, in formulated products, and in foodstuffs as possibly persisting residues. The need for such data has resulted in the exploitation of total chlorine methods for these purposes even though data accrued with such nondefinitive methods must be interpreted with caution.

We have discovered a color reaction to which dieldrin responds and to which the closely related aldrin, endrin, and isodrin will not respond; the color reaction is therefore apparently stereospecific and accordingly should be exploited as a means of assay. Unfortunately, the chemistry of this reaction is complicated and obscure, with the result that the optimum conditions for the production of color must be derived empirically. Some of these conditions have not yet been established, but because of the urgent need for a colorimetric method for dieldrin the present progress summary is being submitted to encourage other workers to investigate the analytical possibilities inherent to this sensitive and specific reaction.

At levels of from 4 to 50 micrograms of dieldrin, when heated with *p*-nitrophenol, the resultant reddish-brown "dye," follows Beer's law with λ max. at 405 mμ and high blanks; at levels of from 50 micrograms to 20 milligrams of dieldrin the resultant clear red "dye" follows Beer's law (with appropriate dilutions above 1 milligram) with λ max. at 520 mμ and low blanks. The experimental procedure below is not always consistent for unknown reasons, but sufficient promising results have been obtained from several hundred attempted assays to merit further study for both production control and residue determinations. For example, a sample of technical grade dieldrin analyzed 78.8 per cent purity by this technique and 79.0 per cent purity by infrared assay. The reaction is inhibited by many substances, including acetone, oxygen, and water; its chemistry is still under investigation in these laboratories.

REAGENTS.—*p-Nitrophenol.*—Crude *p*-nitrophenol is recrystallized 3 times from benzene solutions that have been treated with activated carbon. The fine, pale yellow needles melt at 114° C. and may be stored but should be freshly recrystallized about every 2 weeks.

Nitrobenzene.—Eastman practical grade nitrobenzene is steam distilled from dilute sulfuric acid, dried over anhydrous calcium chloride and finally distilled at reduced pressure; b.p. 118° C./50 mm.

Dieldrin.—Analytical grade dieldrin is freshly recrystallized from medium-boiling petroleum ether; m.p. 175–176° C.

Nitrogen.—Tank nitrogen, preferably scrubbed free from oxygen with chromous chloride solution or Fieser's solution and then dried, is used.

Diethyl Ether.—Reagent grade diethyl ether, freed from peroxides, is stored over excess metallic sodium ribbon.

Nitromethane.—Eastman white label nitromethane is dried over activated alumina and distilled; b.p. 99° C./735 mm.

Paraffin Wax.—Commercial grade paraffin of the type obtainable at grocery stores is melted and vigorously shaken to insure homogeneity. The solid wax is then broken up and used without purification. If this wax interferes with color development it should be washed with hot concentrated sulfuric acid and then copiously with boiling water.

APPARATUS.—*Spectrophotometer.*—Both the Beckman Models DU and B spectrophotometers have been used by the authors.

Reaction Tubes.—Borosilicate test tubes, 13×100 mm., are constricted (about one-half inch from the open end) just to allow the insertion of 3-mm. glass tubing.

Oven.—Any oven that can maintain a temperature of 175°–185° C. is satisfactory.

EXPERIMENTAL.—*Nitrobenzene-p-Nitrophenol Solution.*—This solution is conveniently prepared by weighing about 0.1 gm. of nitrobenzene to within 1 mg. in a stoppered 10-ml. volumetric flask and diluting to the mark with anhydrous diethyl ether. An aliquot of this solution to contain exactly 50 mg. of nitrobenzene is transferred to a 25-ml. volumetric flask into which has been weighed 1.25 gm. of freshly recrystallized *p*-nitrophenol, then diluted to volume with anhydrous diethyl ether. A 1-ml. aliquot of this final solution, containing 50 mg. of *p*-nitrophenol and 2 mg. of nitrobenzene, is suitable

[1] Grateful acknowledgment is made to A. A. Danish and Andre C. Li, Julius Hyman and Co., Denver, Colorado, for their assistance in 1951–1952 in helping develop this reaction.

for use within the range 0.01 to 10 mg. of dieldrin. This reagent solution must be stored in the refrigerator but fresh solutions should be prepared every 2 to 3 days.

Dieldrin.—Desired amounts of dieldrin are introduced into the reaction tubes by the usual weighing and dilution procedures with anhydrous diethyl ether as the solvent. Such solutions appear to be stable indefinitely; however, changes in concentration due to the volatility of ether should be borne in mind.

Preparation of the Sample.—Exactly 1 ml. of the *p*-nitrophenol-nitrobenzene reagent solution and the desired quantity of dieldrin solution are transferred into the constricted test tube. Immersion of the test tube in an oil bath at 35°–40° C. aids solvent removal and lessens the possibilities for condensation of moisture on the sample since even traces of moisture are known to inhibit the formation of color in the subsequent reaction. The ether is evaporated by gently drawing carefully dried air into the sample tube and out a glass tube of about 3-mm. diameter inserted to within about 2 cm. of the surface of the liquid. If evaporation is not started immediately the solution will creep rapidly up the walls of the sample tube. The resulting deposits can be easily washed down by ether from a dropper, and immediate insertion of the suction tube dries the walls of the tube and prevents further creeping. When the sample is completely solvent free, all the solid is contained in the lower 1-cm. portion of the tube.

Approximately 250 mg. of paraffin is added, the tube is swept with dry nitrogen, immersed without shaking in an oil bath at 120° C. to melt the contents completely, and reswept with nitrogen. The tube is then stoppered with a cork having a small capillary leak, and flame-sealed at once without shaking.

Color Development.—The sealed tube is heated in an oven at 180° C. for 5 hours, then cooled. The solid reaction product is dissolved by the addition of 4 ml. of dry nitromethane with careful stirring to break up the insoluble paraffin layer. The reddish-brown to red solution is decanted into a 1-cm. cell through a fritted glass filter and the absorbancy or transmittancy determined at 405 mμ and at 520 mμ.

Reagent Blank.—A reagent blank should accompany each set of samples.

Effect of Calcium Cyanamide on the Rice Borer[1]

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Although the rice borer, *Schoenobius incertellus* Wlk., has been the most serious insect pest of rice in Formosa for many years, no satisfactory control has hitherto been found except burying or burning the rice stubbles during the winter time so as to kill the larvae overwintering in the subterranean culms. Practically, however, this method is not generally welcomed because of the enormous amount of labor required.

In order to determine more economic means of destroying stubbles, a trial was made in the summer of 1950 using calcium cyanamide ($CaCN_2$) as an accelerator for decaying stubbles. From the data obtained it was observed that $CaCN_2$, when applied to infested stubbles in small quantities, not only hastened decay of the stubbles but killed the larvae of the rice borer. Field and laboratory experiments were conducted during 1950–51 to investigate the effectiveness, dosages, and mode of toxicity of $CaCN_2$.

EXPERIMENTAL CONDITIONS.—Field experiments were conducted during harvesttime in November of 1950 and 1951 at Taipei and Chiayi. The plants used were all Honrai variety naturally infested with the rice borer. To investigate the influence of the water content of the upper soil layer, four test plots were selected as follows: severely dried (water content 18 per cent), moderately dried (23 per cent), fully moist (34 per cent), and water (about 3 cm. deep).[2] For the dosage test, each plot was then divided into three sections, each of which received 0.5, 1, or 2 grams of $CaCN_2$ per stubble, respectively.[3] Before the treatment with $CaCN_2$, the soil reaction[2] of each plot was determined. Commercial grade pulverized $CaCN_2$ was applied to each stubble a day after harvest, care being taken that good coverage was obtained on all culms of the stubble. At the same time the influence of stubble height on the control by $CaCN_2$ was also studied. Approximately 40 stubbles were dug every second day for the first 10 days and on the 14th and 18th days after the application, and the effect both on the insect and the stubble was recorded. It drizzled at times during the test period. The average temperature varied from 17.2 to 26.2° C.

EFFECT OF $CaCN_2$ ON THE LARVAE AND STUBBLES.—With several exceptions, to be noted later, the effect of $CaCN_2$ on the insect and on the stubble was usually visible within 3 days following the application. The stubble generally lost its greenish color and withered to some extent. A small quantity of fluid exuded on the inner wall of the subterranean part of a few culms. No such fluid was found in untreated stubble. The mortality of rice borer larvae varied from 11 to 13 per cent on the second day after treatment. Most of the dead and inactive insects were found in culms with the fluid. However, many were also killed in culms not having the fluid. Mortality increased gradually and reached, in most cases, its maximum on the eighth day after treatment. In most cases it varied roughly from 50 to 60 per cent, but in one case it was 73 per cent. During this period the stubbles generally began to decay, exuding more fluid inside the culms, and most of the new growth of the plant withered.

It seems probable that the insect is killed not only through decay of the stubble but also by the action of $CaCN_2$ as a fumigant because usually a number of larvae revived an hour or so after their removal from the culms, though at first they appeared to be dead. Mortality usually ceased within 8 days following treatment. In all cases there were a few stubbles that showed little toxic effect of $CaCN_2$. In such stubbles fewer insects were killed. Mortality in the check plot varied from 0 to 9 per cent during an 18-day period.

DOSAGE AND OTHER FACTORS INFLUENCING THE EFFECT OF $CaCN_2$.—On normal stubbles (about 6 to 18 cm. high), a 0.5-gram dosage showed little effect.

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[2] Water content and reaction of the soil were determined from the surface, about 5 cm. in depth.

[3] A 2-gram dosage is equivalent to approximately 180 kg. per acre, which is the amount used as a fertilizer for the rice crop in Formosa.

However, if the plants were cut at the soil surface this dosage was as effective as 1- or 2-gram dosages on the normal stubble. There was no significant difference in the control obtained with dosages of 1 gram or 2 grams. In fact, mortality varied more because of conditions at time of application than because of differences in dosages.

No effect was obtained when $CaCN_2$ was applied to withered stubble, or to severely dried or to watered soil. Water content and pH of the upper layer of the soil had little influence upon the control within the range tested (23–34 per cent; pH 4.9–5). Except in stubble cut at the soil surface, the height of the stubble at time of application also showed little influence. When $CaCN_2$, even at a dosage of 10 grams per stubble, was applied around the stubble only (i.e., no chemical deposited on the culms), very little mortality occurred although the toxic effect on the plant was visible to some extent.

DISCUSSION.—When $CaCN_2$ is applied to rice stubbles when they are fresh and are on soil of proper moisture content, some toxicant derived from the hydrolysis of $CaCN_2$, deposited on the culms may penetrate the tissues of the plant. As a result the culm tissue is destroyed, generally exuding more or less fluid. When such fluid is sufficient to cover the insect, it is clear that mortality would occur from suffocation even if the fluid were nontoxic. Actually, however, such culms were few in number and many insects were killed in the culms having little or no fluid. This suggests that the insects were killed not only by the fluid but also by some toxic agent formed in the culms. To determine the lethal agent positively, several tests were made during the year 1950–51. Although no definite conclusion resulted from these, it was found that the insect was not killed simply by asphyxiation;[4] also that mortality due to ingestion of the culm tissue as a stomach poison was probably negligible. The effect of $CaCN_2$ entering into the culms also appeared to be negligible.

Because mortality usually occurred as early as the second day following the application of $CaCN_2$ and prior to apparent decay of the culms, and because some insects were always killed in nondecaying culms throughout the period of these tests, it is concluded that cause of death was due both to decay of the stubble and to some autonomous toxicant derived from $CaCN_2$, which probably acted as a fumigant.

The fact that $CaCN_2$ was ineffective when applied on severely dried soil can be interpreted as due to a lack of its hydrolysis, and in turn the formation of the toxicant in the plant tissue. Ineffectiveness of $CaCN_2$ when applied to withered stubble, or only around the stubble, seems to be due to nonformation of the toxicant in the culm tissue. Variation in mortality observed in these tests may be partly due to the variation in the dosages of $CaCN_2$ applied to the individual culms of stubble.

SUMMARY.—Field experiments showed that $CaCN_2$, when applied to the rice stubbles while they remained fresh on properly moistened soil, was effective against the rice borer larvae overwintering in the subterranean part of the culms.

With several exceptions, the kill by $CaCN_2$ took place within 2 days after the application, during which the mortality varied from 11 to 13 per cent. It increased gradually and usually ceased after 8 days; during this period the mortality varied from 50 to 73 per cent. The insect seems to be killed not only through decay of the stubble caused by the $CaCN_2$ but also by some autonomous toxicant derived from $CaCN_2$, which probably acts as a fumigant.

A dosage of 0.5 gram was as effective on stubble cut at the surface of the soil as 1 or 2 grams applied to normal stubble, 6 to 18 cm. high.

The Digestive Enzymes of the Firebrat

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The determination of the digestive enzymes in the alimentary canal of the firebrat, *Thermobia domestica* (Pack.), a common household pest in New York State, has not previously been investigated. However, it has been known for some time that a number of foods found around the home were attractive to this insect. The work of Berger (1945) further demonstrated that the firebrat could pick and choose from among these available foods. This information indicated a similarity in feeding habits between domestic cockroaches and silverfish and further suggested the possibility of a similarity of digestive enzymes. Swingle (1925) established that there were carbohydrate, fat, and protein digesting enzymes in the digestive tract of the oriental cockroach *Blatta orientalis* L. Therefore, to determine the exact enzymes present in the digestive tract of *T. domestica*, a study was undertaken.

METHODS.—Several adult Thysanura were killed in cyanide, embedded in paraffin, covered with physiological saline solution and the digestive tracts removed. The digestive tracts were ground up with a mortar and pestle. A small amount of distilled water was added to dilute the enzymes and create enough solution to use in the tests. The enzymes and substrate were placed in micro tubes approximately 3 inches long, made from 10 mm. glass tubing. The incubations were carried out in a controlled temperature cabinet at 37 degrees C.

The checks were made by substituting distilled water for the enzymes in each test. The alkalinity or acidity of the checks was adjusted to that employed in the corresponding test. To each test and check in the micro tubes, toluene was added to prevent the action of micro-organisms. The tubes were sealed by heating and drawing in a bunsen burner flame, following the addition of the enzymes and substrate, or water and substrate.

The chemical tests employed were those of Swingle (1925) with one slight modification.[2]

RESULTS.—The results obtained are shown below in tabular form.

Enzyme	*Reaction*
Amylase[3]	negative
Maltase	positive
Invertase	positive
Lactase	negative
Lipase	positive
Pepsin	negative
Trypsin	positive
Erepsin	positive

[4] The mortality of overwintering full grown larvae confined in CO^2 or in water for 8 days was 17 per cent and 33 per cent, respectively.

[1] New York State College for Teachers and Albany Medical College, Albany, respectively.

[2] Picric acid was employed as the staining agent for fibrin in the test for pepsin.

[3] The salivary glands, the probable source of this enzyme, were not included in these tests.

CONCLUSIONS.—*Thermobia domestica* (Pack.) has starch, fat and protein digesting enzymes present in the digestive tract and therefore is capable of utilizing a variety of materials of both animal and vegetable origin as a food source.

The similarity between the digestive enzymes of *Thermobia domestica* and *Blatta orientalis* L. indicates that the nutritional essentials of domestic cockroaches and silverfish are closely allied.

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The Insecticidal Value of *Tripterygium wilfordii*

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The roots of *Tripterygium wilfordii* Hook f. have been used for centuries by Chinese market gardeners to protect their crops against insect pests (Shepard 1939). These roots contain alkaloids that are poisonous to certain chewing insects. Cuttings of the plant were imported into this country in 1936 and grew well in the U. S. Department of Agriculture Plant Introduction Garden at Glenn Dale, Maryland. The plant has since been grown experimentally in other parts of the country. The history and preliminary entomological results obtained with *T. wilfordii* root have been reported by Swingle *et al.* (1941). Tattersfield *et al.* (1948) have confirmed the insecticidal action of the root powder on the young larvae of the diamondback moth, *Plutella maculipennis* (Curt.).

Acree and Haller (1950) isolated a crystalline alkaloid, wilfordine, which exhibited high toxicity to larvae of the codling moth, *Carpocapsa pomonella* (L). Their studies on the structure of wilfordine showed a discrepancy between the sum of the isolated component parts and the molecular formula. It was later shown that this discrepancy was due to the fact that wilfordine is a mixture composed mainly of five similar alkaloids (Beroza 1950). All these alkaloids were found to be insecticidally active and were called wilforine, wilforgine, wilfordine, wilfortrine, and wilforzine (Beroza 1951, 1952, 1953), the name "wilfordine" being retained for the most abundant alkaloid in the mixture.

The presence of these alkaloids was first demonstrated by countercurrent distribution, and the isolation of each was accomplished by partition chromatography. The alkaloids are complex esters having a molecular weight close to 900. Degradation studies have shown wilforine, wilforgine, wilfordine, and wilfortrine to possess the same polyhydroxy nucleus, which has 8 of its 10 hydroxyl groups esterified in the intact alkaloid—5 with acetic acid, 1 with benzoic or 3-furoic acid, and 2 with a nitrogen-containing dicarboxylic acid (Beroza 1953). The 3-furoic acid is a rare acid that has been isolated from a natural source only twice before. The dicarboxylic acid is a 2-substituted nicotinic acid derivative. Wilforzine has the same chemical structure as wilforine except that it contains one less acetyl group (Beroza 1953).

In the course of these chemical studies entomological data were obtained by a number of investigators of this Bureau. A study of the toxicities of four of the pure alkaloids to newly hatched larvae of the European corn borer, *Pyrausta nubilalis* (Hbn.), was made by D. D. Questel (unpublished). The insects, held in glass test tubes with cellulose stoppers, were fed corn leaves treated with a spray containing 60 p.p.m. of the pure alkaloid (8 pounds of pyrophyllite containing 0.6% of the alkaloid made up to 100 gallons with water). The percentages of larvae killed are shown below.

	After 2 days	*After 3 days*
Wilforine	88	100
Wilforgine	30	54
Wilfordine	54	100
Wilfortrine	48	73

Leaves treated with a spray containing 60 p.p.m. of the noncrystalline fraction remaining after removal of the crystalline material gave about 90 per cent kill of European corn borer larvae after 2 days. In another test leaves treated with a spray containing 4 pounds of root powder per 100 gallons of water killed 81 and 96 per cent of the larvae in 48 and 72 hours, respectively.

Subsequently wilforzine was isolated, but insufficient material was available for comparative tests. However, wilforzine exhibited definite, but much less, insecticidal action than wilforine against larvae of the diamondback moth.

Further tests showed that *Trypterygium wilfordii* root powder was effective against the green dock beetle (L-3),[2] *Gastrophysa cyanea* (Melsh), and the pepper weevil, *Anthonomus eugenii* Cano (Campbell 1944), and showed some toxicity to larvae of the Mexican bean beetle (L-3, 4), *Epilachna varivestis* Muls. (N. F. Howard, unpublished), and the cross-striped cabbageworm (L-4), *Evergestis rimosalis* (Guen.). It also showed some toxicity to the armyworm (L-1, 3), *Pseudaletia unipuncta* (Haw.); the celery leaf tier (L-3), *Phlyctaenia rubigalis* (Guen.); and the Hawaiian beet webworm (L-2), *Hymenia recurvalis* (F.). In general, the smaller larvae were affected more than the larger ones. The powder was completely ineffective against the tomato fruitworm (L-5), *Heliothis armigera* (Hbn.) (N. F. Howard, unpublished); the large milkweed bug, *Oncopeltus fasciatus* (Dall.); the salt-marsh caterpillar (L-3), *Estigmene acrea* (Drury); the pea aphid, *Macrosiphum pisi* (Harris) (Dudley *et al.* 1945); the pea weevil, *Bruchus pisorum* (L.) (T. A. Brindley, unpublished); *Autographa oo* Cr. (L-4); and the screwworm (L-1), *Callitroga hominivorax* (Coq.) (R. C. Bushland, unpublished). It was also ineffective against adult blister beetles, *Epicauta* spp., and adult Mexican bean beetles. The Pacific Coast wireworm, *Limonius canus* Lec., and the sugar-beet wireworm, *L. californicus* Mann., were not affected by hot-water or 1-per cent acetone or ethanol extractives of the root powder (M. C. Lane, unpublished). Nymphs and adults of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, were likewise not affected by the root powder. Tests to determine contact toxicity to the melonworm (L-4, 5), *Diaphania hyalinata* (L.), and the imported cabbageworm (L-4, 5), *Pieris rapae* (L.), gave negative results.

The root (50 mg./ml. in Deobase) was nontoxic to the house fly, *Musca domestica* L., and showed no synergism with pyrethrins. As bait toxicants for

[1] Now with U.S.D.A., Foreign Agricultural Service.

[2] L-3, 4, etc., indicate the larval instar.

house flies both the root and the noncrystalline alkaloid were ineffective, but the latter was somewhat effective as a mosquito larvicide, giving 100 per cent mortality in 48 hours at 10 p.p.m. and 16 per cent at 0.1 p.p.m. The root was of no value as a repellent or stomach poison against the Japanese beetle, *Popillia japonica* Newm. (W. E. Fleming, unpublished).

Of interest in connection with the use of *Tripteryygium wilfordii* as an insecticide is its toxicity to warm-blooded animals. Three baits were prepared and fed to rats. One bait contained 20 per cent of the ground whole root, the second 0.5 per cent of the noncrystalline alkaloid, and the third 0.5 per cent of the crystalline alkaloid. Apparently the materials are nontoxic, since no symptoms of poisoning were observed.

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A Codling Moth Population Resistant to DDT

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In 1944 and again in 1945 the apple crop in the orchard of the Hamilton County Experiment Farm suffered severely from codling moth attack. Approximately 80 per cent of the fruits were damaged in 1944 despite the use of lead arsenate in the petal fall and six cover sprays. In 1945 DDT was available for experimental use and a comparison was made between plots sprayed with this material and plots treated with lead arsenate. Both series of plots received five cover sprays, with the lead arsenate being used at 3 pounds per 100 gallons and the DDT at 1 pound actual (4 pounds 25% wettable powder per 100 gallons). The results are summarized as follows.

Lead arsenate schedule—12.0% wormy, 39.0% stung

DDT schedule—0.5% wormy, 1.8% stung

These very favorable results led to the adoption of a DDT spray schedule for the orchard which has been continued through 1953.

However, in 1951 the farm superintendent reported that codling moth control was not satisfactory. Because of this, a portion of the orchard was sprayed with a parathion schedule in 1952 and much better control was secured than in the remainder of the orchard that was treated with DDT. The data of 1952, however, were fragmentary and as there was no attempt at replication no proof of resistance on the part of codling moth to DDT could be shown.

It was, therefore, decided to conduct a scientifically planned field experiment in the orchard during the 1953 season that would prove or disprove the occurrence of resistance to DDT by the codling moth. This was done by using six different spray schedules in the orchard, each one of which appeared upon eight replicates, in randomized blocks. The experimental spray schedules were started on May 21 at the time of the first cover spray and were continued to August 4. A total of seven spray applications were made. On July 10, preliminary counts were made that indicated a definite difference between treatments. Final counts were made on September 8 and the summarized results are given in table 1. These results are based on samples taken from the entire crop including both dropped and picked fruits from each replicate.

An inspection of the table shows the tremendous difference that existed between the DDT treated plots and those treated with the other materials. It should be noted that little or no benefit in control was gained by increasing the dosage of either DDT or parathion. As lead arsenate had not been used against the codling moth since 1945, when it was entirely ineffective, the result with this material is of interest. In view of the past history of the orchard

Table 1.—Codling moth control. Hamilton County Experiment Farm, Cincinnati, Ohio, 1953.

PLOT NO.	MATERIALS[1] AND AMOUNTS PER 100 GALLONS	WORMS PER 100 APPLES
1	Lead aresenate, 3 lbs.	14.6
2	DDT 50% WP, 1½ lbs.	95.8
3	DDT 50% WP, 2½ lbs.	94.3
4	Parathion 15% WP, 1½ lbs.	10.4
5	Parathion 15% WP, 2½ lbs.	10.1
6	Dilan, 2 lbs.	24.7
	L.S.D. 1% for treatment	40.7

[1] All materials used in 7 applications. Ferbam was the fungicide in the first 5 applications. Captan was used in the last two.

and the conclusive nature of the data secured in this experiment, it is quite evident that this population of the codling moth has developed a resistance to DDT.

Potato Flea Beetle Control with New Insecticides

GEORGE E. GOULD and L. L. MCCROSKY[1]

A large increase in the potato flea beetle population was first noticed on the Gumz farms during 1951. During that season potatoes receiving the customary 8 to 12 applications of the standard DDT-fungicide spray still had a large population of beetles and extensive feeding on the foliage. The standard dilution for DDT on this farm has been 3 pints of the 25 per cent emulsion concentrate, or three-fourths pound actual chemical, per acre per application. These applications were made at weekly intervals during the season with DDT in at least the first six or seven and usually in the eighth and tenth sprays. Fungicide applications were made up to a few days before harvest with often as many as 15 in all. This spray program has given excellent control of the potato leafhopper, the principal pest of potatoes in Indiana, and apparently satisfactory control of the flea beetle prior to 1951.

The species of flea beetle present on potatoes in Indiana is mostly *Epitrix cucumeris* (Harr.). The principal injury is damage to the foliage by feeding of adults and only once has tuber injury by the larvae been observed. In this case the adults moved in large numbers from early-harvested Cobblers to the first 20 adjacent rows of a late variety.

The failure of DDT to hold the beetle in check in 1951 lead to a careful examination of various treated fields the following year. Materials from three manufacturers were used on the first three applications and failed to reduce the early populations of the beetle. Consequently Metacide was substituted. Examinations on other farms in northern Indiana indicated that all were experiencing the same difficulty in checking flea beetle feeding. During the season most growers changed to one of the phosphorus compounds and had excellent control of the flea beetle and fair to good control of the leafhopper. Growers were also pleased with the absence of aphid infestations which usually developed when the DDT schedule was followed throughout the season.

In 1953 plots were arranged in a commercial field on the Gumz farm to determine the efficiency of several insecticides and of variations in the dosage rate for DDT. Adjacent to the experimental area was a corn field with numerous volunteer potato plants which served as a continuous source of reinfestation. All spray applications were made with the regular 12-row potato sprayer, which applied 75 gallons of material per acre at a pressure of 300 to 400 pounds. Applications were made on May 28, June 1, 9, 15, 22, and 30 with the following materials:

1. DDT emulsion with 1½ pounds active ingredient per acre on applications 1, 2, 4, and 5.
2. Heptachlor emulsion with ¾ pound per acre on the first five applications.
3. Dieldrin emulsion with ¾ pound per acre on the first five applications.
4. DDT emulsion with 1½ pounds per acre on applications 1 and 2. DDT emulsion with 1 pound per acre on applications 3 and 5.
5. DDT emulsion with 2 pounds per acre on first five applications. Metacide was used on all plots for the sixth application (June 30) and was also used on the remainder of the field throughout the year.

In May and early June the population was high in the plots, but after the second application the number was reduced in plots 2, 3, and 5. The untreated volunteer potatoes had a high population until late June when cultivation and hoeing of the corn eliminated these plants. Since flea beetles are active and difficult to count, the efficiency of the various treatments was determined by the number of feeding punctures per leaf. These counts were made in an area about 50 feet from the edge of the field in order that flea beetle migration would influence all plots equally. In making counts the third mature leaf from the top was selected and a total of 20 were examined per plot. The first count was made on June 16 and the final count July 1 and the leaves had an average number of feeding punctures as follows:

	June 16	*July 1*
1.	105	137
2.	51	25
3.	26	6
4.	73	112
5.	17	21

SUMMARY.—The application rate for DDT of 1¼ pounds active ingredient per acre per application was not satisfactory in reducing flea beetle damage, although the 2 pound rate gave reasonably good control. Commercial applications of one of the new organic phosphorus insecticides have been satisfactory, but the substitution of such a compound for the third and sixth application of the standard DDT was not sufficient. Two new insecticides, dieldrin and heptachlor, used at a rate of ¾ pound per acre per application gave excellent control.

Parathion Residues on Peach Bark and Foliage

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Since parathion came into general use as an insecticide for plum curculio control, it has been observed that San Jose scale and Forbes scale infestations have decreased to the extent that the majority of peach growers in Virginia no longer apply dormant sprays for scale control. It was known that parathion sprays would kill scale crawlers, but since parathion has generally been considered as having a short residual life, there was a question as to how the parathion sprays applied for plum curculio control could significantly affect scale crawlers from 3 to 5 weeks after the last application.

Studies on parathion residues on peach tree foliage, fruit, and bark were begun in 1952, and this report summarizes the work on bark and leaves during 1952 and 1953.

METHODS AND MATERIALS.—In 1952 the sprays were applied with a high-pressure spray machine using a hand gun, but in 1953 the sprays were applied with a sprayer having a blower unit (*Hardie*

[1] Entomologist, Purdue University, Lafayette, Indiana and Agronomist, Richard Gumz Farms, North Judson, Indiana, respectively.

Table 1.—Micrograms of parathion per 100 square centimeters of leaf and bark surface on peach trees in specified weeks after the last spray application, 1952.

Weeks After Sprays	Total Rainfall Since Spray (Inches)	Dilute (1½ Pounds per 100 Gals.)	
		Leaves	Bark
0[1]	0.00	138.1	319.3
1	0.76	2.8	204.1
2	2.40		145.6
3	2.40		121.0
4	2.40		114.8
5	2.60		67.2

[1] Sample taken as soon as spray dried.

Table 2.—Micrograms of parathion per 100 square centimeters of leaf and bark surface on peach trees in specified weeks after the last spray application, 1953.

Weeks After Sprays	Total Rainfall Since Spray (Inches)	Dilute (1½ Pounds per 100 Gals.)		Concentrate (4½ Pounds per 100 Gals.)	
		Leaves	Bark	Leaves	Bark
0[1]	0.00	112.1	276.2	71.1	264.9
1	0.66	1.6	188.4	2.2	159.7
2	0.78	0.4	141.9	0.5	81.0
3	2.64		116.0		69.6
4	2.77		119.2		71.2
5	5.44		59.0		68.4

[1] Sample taken as soon as spray dried.

Air King). Parathion was used at the rate of 1½ pounds of 15 per cent wettable powder per 100 gallons of water for dilute spraying or 4½ pounds per 100 gallons for concentrate spraying. Each tree received approximately 4½ gallons of dilute spray or 1½ gallons of concentrated spray. In 1952 the sprays were applied on May 1 (shuck-fall) and May 16 (first cover), and in 1953 they were applied on April 11 (shuck-split), April 22 (shuck-fall), and May 4 (first cover). Each plot consisted of approximately 40 trees of the Elberta variety.

The bark samples were taken from 12 randomized trees in each plot each week. The samples consisted of pieces of wood from 1 to 1¼ inches in diameter and from 6 to 10 inches long. The leaf samples consisted of from 250 to 300 leaves, which were likewise taken at random from trees in each plot. In order to avoid collecting leaves which had developed since the last spray was applied, only leaves showing visible residue were collected. Leaves as near the same size as possible were collected each week. Analyses for residue were made by the Division of Chemistry, Virginia Department of Agriculture and Immigration, Richmond.

RESULTS.—The last plum curculio spray for first-brood control is generally applied in early to mid-May, and San Jose scale and Forbes scale crawlers are most numerous in late May and early June.

Tables 1 and 2 give the parathion residue found on bark and leaves of peach trees each week and the total cumulative rainfall since the last spray application for 1952 and 1953, respectively. The initial dosage on bark was much greater than on leaves and apparently an effective parathion residue remained on bark much longer than on leaves. Rainfall had no significant effect on the weathering process. The amount of residue deposited on foliage and bark receiving the concentrated spray was slightly less than that on trees receiving the dilute spray, and the residue from the concentrated spray weathered more rapidly.

SUMMARY.—The residual effectiveness of parathion on leaves of peach is less than 1 week. Residues on bark, however, remain effective for a much longer period, and lethal residues to San Jose scale and Forbes scale crawlers remain for at least 4 weeks after applications.

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91st Annual Meeting

ENTOMOLOGICAL SOCIETY OF ONTARIO

Sault Ste. Marie, Ontario,

November 1 to 3, 1954

EDITORIAL

Natural Control of Insect Pests

In developing an insect control program, every possible consideration should be given to preserving and utilizing the natural agencies of control. Sound chemical control programs can be most satisfactorily developed only where all factors in the environment are considered. To obtain greatest benefit from natural enemies, application of insecticides should be timely, they should be applied with effective equipment under favorable weather conditions, and used at the lowest possible concentration that will insure satisfactory control. Frequent application of insecticides should be avoided in order to minimize interference with natural enemies.

The natural factors in the environment which tend to suppress pest populations are the entomologist's greatest allies, and should be utilized to their fullest possible extent in the development of insect control programs. The taks of correlating natural control with chemical control is a difficult one, and has often been ignored. In many cases there has been the tendency to lean too heavily upon the new insecticides without giving proper consideration to the natural controlling factors. True enough, some of these newer materials result in outstanding control of certain insects, and superficially, at least, it appears that because of the complete kill obtained little concern need be given natural control. While such a short-range view might be taken, it appears that in the long run natural control will be found to be indispensable.

In order to preserve the value of some of our most useful insecticides, their use should be limited to those occasions where the pest population is sufficiently large to justify their application. One of the most serious threats we have encountered is the selecting out, or the development of resistance, to certain of our key insecticides by insects. A case in point is the development of resistance of the house fly and certain mosquitoes to DDT and related insecticides. Now it appears that, among others, *Lygus* bugs are exhibiting resistance to DDT and in our own investigations we have encountered a strain of walnut aphid, *Chromaphis juglandicola* (Kltb.), definitely resistant to parathion. If the trend continues and more and more insects are added to the list, economic entomologists may find themselves faced with a most serious problem.

One among the many contributing factors in the selecting out of resistance is probably too frequent and sometimes uncalled for use of insecticides. Such a procedure is likely to favor the development of a resistant population potential. Treatments often are applied before the pest population reaches a level to justify such measures or where the population, although approaching an economic level, is of little concern because of a sufficient number of natural enemies to hold it under control. For example, where alfalfa is grown for seed, as many as five or six applications of DDT have been made during a season to control *Lygus* bugs. The level of population at which most treatments were made was one individual bug per sweep. It is not difficult to see how this procedure would have a tendency to select out resistance if it were in the *Lygus* population. The walnut aphid is so feared as a pest that in certain areas there has been a tendency for growers to treat at extremely low population levels or where natural agencies were effectively checking the population. Here again is an example where treatment without need favors the selection of resistance.

Treatments that adversely affect natural enemies can result in destructive outbreaks of pest populations. The application of amounts of DDT larger than necessary to control the codling moth on walnuts has resulted in destructive outbreaks of the frosted scale, *Lecanium pruinosum* Coquillett, and spider mites. Yet neither of these pests is likely to be troublesome when the amount of actual DDT applied does not exceed 4 pounds per acre. This dosage is sufficient to give adequate control of the codling moth when applications are timely and thoroughly applied. In the case of the frosted scale, it is easy to demonstrate that the increase in population is due to the harmful action of the DDT residue upon the parasites of this scale when the insecticide

is applied at rates much higher than that needed to control the codling moth. In the case of spider mites, high dosages of DDT appear to exert either a physical or physiological action as well as adversely affecting the natural enemies. Yet where DDT is used at the recommended dosage the efficient action of natural enemies is evident. Spider mites usually make their appearance, but in contrast to the devastating populations that occur where high dosages of DDT are used, the population remains small and is almost immediately attacked by predators, of which *Stethorus* appears to be the most important. Serious spider mite populations fail to develop, incipient infestations are all but eliminated and the dispersion of predators throughout the trees and orchard as the season progresses gives assurance that natural control will prevail.

The systemic insecticide demeton has been used with outstanding success in the control of the walnut aphid. Treatments applied in early May have remained effective until after midsummer. However, natural enemies become established as soon as the aphid regains a foothold and while there is some increase in the aphid population there is a tendency for it to be adequately checked by predators. Even when the non-systemic insecticides are used in walnut aphid control, the aim has been to all but eliminate the host population from the treated area so that the natural enemies will have an opportunity to re-establish themselves at about the same time as does the aphid.

In the walnut aphid investigations at Linden, California, 14 per cent nicotine dry concentrate has been included among the treatments. Interestingly enough, the plots treated with this insecticide have rated high in comparison with the newer insecticides such as benzene hexachloride, parathion, malathion and TEPP. During the last two years slightly better control has been obtained with nicotine than with any of the other mentioned materials. The indicated superiority in the case of nicotine is believed to be due to its slight adverse effect upon natural enemies. This advantage is greatly magnified when it is compared to parathion in an area where the walnut aphid exhibits resistance to the latter insecticide.

Where insecticides are destructive to natural enemies it is of utmost importance to obtain excellent control of the pest population. Disastrous results sometimes follow the application of an insecticide that all but eliminates the beneficial insects, but produces a relatively poor kill of the destructive pest. Under such conditions the pest population may multiply to a very damaging level in 10 to 14 days. In some cases, as with certain scales, the havoc produced does not become apparent for some time. However, the sudden upsurge of the destructive species certainly is an excellent illustration of what can happen if natural control is too greatly disturbed. Even in such cases natural enemies will usually gain the upper hand, but this seldom occurs before a great deal of damage has been done. Under severe conditions the development of the pest population may be so rapid that defoliation or destruction of the crop is brought about before the natural enemies have an opportunity to check the infestation.

There are cases where the use of the newer insecticides exhibited no adverse effect upon the host-predator relationship. An excellent illustration is where DDT is used for the control of *Lygus* bugs. The DDT dosage needed for the effective control of this insect apparently has little adverse effect upon important bug predators such as anthocorids, minute pirate bugs, *Geocoris* spp., big-eyed bugs, and the common damsel bug, *Nabis ferus* (L.). As a matter of fact, numerous observations have been made where applications of DDT have actually improved the host-predator balance.

Any sound control program has as its objective the continued suppression of the pest populations below an economic level. There is little value in controlling one pest if the treatment results in the increase of another that is equally destructive. To avoid this situation as much as possible, it has been found desirable always to use an insecticide at the lowest concentration that will result in satisfactory control. In the melon insect control investigation, DDT was found to be highly effective against most of the principal pests but its use was likely to result in destructive populations of the melon aphid, *Aphis gossypii* Glov., and spider mites. These adverse effects, although not eliminated, were greatly re-

duced by using DDT at the rate of not more than a pound of active ingredient per acre. This dosage usually did not unduly affect the natural enemies of the melon aphid, and at the same time if it was thoroughly applied resulted in excellent control of cucumber beetles, *Diabrotica undecimpunctata* Mann. and *Acalymma trivittata* (Mann.), and a melon leafhopper, *Empoasca abrupta* DeLong. The low dosage of DDT frequently resulted in no increase in spider mites, but where it did, the problem could be met only by applying an acaricide. Certain problems can be combatted only through the use of a combination of insecticides.

There is no question but that the development of new insecticides during the past decade has greatly expanded the possibilities of insect control. Yet as remarkable as some of the new materials are, it appears that their fullest and most prolonged use will depend on developing programs that utilize natural control (both its biological and physical aspects) to the maximum.

A. E. MICHELBACHER,
University of California, Berkeley

Observations on Fly Control by Sanitation

ROBERT A. HOFFMAN, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The writer had an opportunity to observe fly control obtained by strict sanitation of premises near Fresno, California, during the 1953 fly season. The effect of rigid sanitation and lack of attractants was outstanding on one grade-B dairy farm. He therefore thought that a report of the practices and conditions would be of interest to medical and veterinary entomologists.

Periodic observations were made of this farm throughout the summer, and at no time were more than 20 flies counted in the interior of the dairy. Attempts to obtain fly counts by either molasses-baited or Scudder-type grids failed completely.

The farm buildings were not modern structures. Both the barn and the milking parlor were in one old wooden building. Floors were of wood planks and stanchions of unpainted boards. No screens were at the windows. Adjacent to the barn was a dirt corral used to hold animals awaiting milking. Next to the corral was a 1-acre dry lot used to keep the dairy herd of 38 cows at night. At all other times the dairy animals, 40 beef animals, and 2 horses were kept on irrigated pasture within ¼ to ½ mile of the barn. Young calves were kept in small pens near the barn, as is the common practice in the region.

Although the premises were old and worn, the operator of the farm was meticulous in cleaning the milking parlor daily and scattering manure in a thin layer in the dry lot to be baked dry in the sun. Only rarely was water used to clean the barn floor; daily cleanup was generally done with a stiff, dry, long handled brush and a shovel. The dirt corral was likewise swept regularly with a broom and the manure spread. As little water was used in the barn cleaning, no sump or liquid manure pit was required. The calf pens were kept clean and dry. Unlike nearly all other farms visited, no enriched feeds or fly-attractive additives were used in the cattle feed. Milk and milk products were never left uncovered, and no excess feed was allowed to accumulate in the racks. The milking parlor had received one residual application of a chlorinated hydrocarbon insecticide in April, but no residual spray was applied thereafter. In mid-August field-captured flies exposed to the walls under petri dishes were not affected by the contact. The only other insecticidal practice was a daily pyrethrum spraying of the cows at milking for the control of horn flies.

The density of flies at other grade-B dairy farms in the community was observed as a check of normal fly populations. One typical farm was within one-half mile of the farm described. The operator observed only the usual precautions—stock-piled manure for spreading at a later date, cleaned corrals and pens occasionally, and washed the milk parlor with water to an open sump. Fly populations of 20 to 50 per minute were obtained repeatedly with the baited grid, even though the barn and milking parlor were sprayed several times during the season.

It has been demonstrated, therefore, by one dairy farmer operating in an area of lower rainfall and humidity that rigid sanitary conditions and proper storage of food can measurably reduce fly populations in dairies. On his farm the use of insecticides was reduced to a minimum. Lack of attractants minimized the numbers of house flies that migrated to the farm.

ENTOMOLOGICAL SOCIETY OF AMERICA

Proceedings of the First Annual Meeting Following the Consolidation of the American Association of Economic Entomologists and the Former Entomological Society of America

December 7–10, 1953

Los Angeles, California

The newly organized Entomological Society of America held its first annual meeting at the Biltmore Hotel. A total of 673 entomologists registered, not all of whom are members of the Society. About 100 other entomologists and members of families are believed to have attended.

During the two days prior to the beginning of the meeting, and during the four-day meeting period, the Interim Governing Board held various meetings. The 1954 Governing Board met on the afternoon of December 10. While many matters of policy were discussed, the main items of business on which definite action was taken are indicated in the report of the two general business sessions of the Society, which are published on the following pages. One of the first matters discussed by the Interim Governing Board was the financial condition of the Society and the appointment of a salaried Executive Secretary. Dr. Ashley B. Gurney of Washington, D. C. was appointed, effective January 1, 1954, with a brief period as Acting Executive Secretary subsequent to December 15, 1953, the exact dates of that service to be arranged to the mutual satisfaction of Dr. Gurney and the retiring Interim Secretary-Treasurer, Dr. E. N. Cory. (The actual transfer of responsibility later occurred on December 19.)

Various special committees were appointed in 1953, and their reports were received by the Interim Governing Board. Unlike the reports of regular Standing Committees of the Society, however, reports of most special committees will not be published. Reports of several Sections and Sub-sections, dealing with Sections and Sub-section sessions at Los Angeles, have been submitted, and it is expected that the essential data in those reports will appear later in newsletter form. Likewise, it is anticipated that a list of members and data on membership growth will be published later. It should be noted that the financial report for 1953, as taken from the Audit Report, is not representative of a current business year, because bills for dues and subscriptions were sent to members twice in 1953. This situation was peculiar to the first year following amalgamation.

Proceedings of Business Meetings

Opening Session, December 7

The meeting was called to order at 9:45 by Roy E. Campbell, Chairman, Local Arrangements Committee. The National Anthem was followed by the Pledge of Allegiance to the Flag. Mr. Campbell and C. H. Littooy made several local announcements. Pres. Charles E. Palm brought greetings from the Entomological Society of Canada, and he briefly outlined procedures to be followed, for program purposes, in recognizing new sub-sections for the next Annual Meeting.

President-Elect H. H. Ross took the chair and presented Pres. Palm who gave the presidential address.

Pres. Palm then took the chair again and paid a high tribute to Dr. Ernest N. Cory, retiring Secretary-Treasurer, and Prof. L. M. Peairs, retired Editor of the Journal of Economic Entomology.

Dr. Palm spoke as follows: "Through the years it becomes more evident that among our truly great possessions in this life are the friends we make. In any great organization there are a few who by interest, ability and self-sacrifice and genuine love of their fellow man, render service and friendship to all members above and beyond the call of duty. The unfortunate part about it is that usually the efforts of these men and women appear to be taken for granted without proper recognition.

"Dr. Ernest N. Cory and Dr. Leonard M. Peairs for many long years have served the profession of entomology in a very real and noble sense through their work as Secretary-Treasurer of the American Association of Economic Entomologists and as Interim Secretary of the Entomological Society of America, and as Editor of the Journal of Economic Entomology. Their friends in the profession are in all parts of the world.

"I deem it a very great privilege to have been selected by this host of friends to act as their spokesman, to express publicly the genuine affection that we feel for Dr. Cory and Dr. Peairs, and to say once again, with all sincerity, thank you for the grand job well done for entomology and for your friendship through the many pleasant years of the AAEE. We appreciate also your continuing help during this transition period of building a new and broader organization, the Entomological Society of America.

"As a token of our great esteem, Dr. Cory and Dr. Peairs, your multitude of friends from the old American Association of Economic Entomologists and now the new Entomological Society of America, have asked me to present to you these gifts, with the hope that they will ever remind both of you daily of our affection for you and of our deep appreciation for all you have done and are doing for all of us."

A watch was then presented to Dr. Cory and the entire assembled audience rose in tribute. Dr. Cory spoke briefly and acknowledged the high tribute which had been accorded him by his many friends. Dr. Palm explained that a similar watch would be sent to Dr. Peairs, who was unable to attend the meeting. Dr. R. L. Usinger and Mr. L. S. Hitchner then presented scheduled invitation addresses, following which was a brief intermission.

Preliminary Business Meeting

1. Pres. Palm introduced Dr. A. B. Gurney who spoke briefly in acknowledgement of his forthcoming responsibilities as Executive Secretary.

The President acknowledged the fine work of Howard Baker and other members of the Program Committee, and of many others who contributed to making the Annual Meeting successful.

2. Dr. Cory gave a report on the business affairs of the Society, including the audit of November 30, 1953. He moved, Dr. H. M. Harris seconded, that the report be accepted. Carried.
3. Pres. Palm briefly discussed the Standing Committees, and Dr. Cory presented the names of those previously agreed upon by the Interim Governing Board. There were no nominations from the floor. Dr. Cory moved, H. M. Armitage seconded, that the nominees be elected. Carried. The following Committees were elected and the respective chairmen were later selected by Pres.-Elect Ross.

MEMBERSHIP COMMITTEE

A. F. Kirkpatrick
Herbert Knutson
Sherman W. Clark
L. C. Murphree
P. W. Oman
H. H. Schwardt, *Chairman*

PROGRAM COMMITTEE

R. C. Bushland
C. C. Alexander
C. W. Sabrosky, *Chairman*

COMMITTEE ON COMMON NAMES OF INSECTS

A. V. Mitchener
D. E. Parker
H. O. Deay
J. B. Schmitt
A. E. Michelbacher
D. Elmo Hardy
R. T. Robb
C. E. Smith
R. I. Sailer, *Chairman*

COMMITTEE ON INSECTICIDE TERMINOLOGY

Allen B. Lemon
Millard Swingle
C. O. Eddy
Geo. S. Kido
Clyde W. Kerns
H. L. Haller, *Chairman*

COMMITTEE ON ENTOMOLOGICAL NOMENCLATURE

George Steyskal
Howard E. Evans
Richard M. Bohart
Stuart Walley
C. W. Sabrosky
J. C. Bradley
P. W. Oman
C. D. Michener
R. L. Usinger, *Chairman*

4. Dr. Cory exhibited Index XI of the American Economic Entomology, and stated that Volume IX is now ready for the printer.
5. Pres. Palm made several brief local announcements.

Adjournment at 12:10 P.M.

FINAL BUSINESS MEETING, DECEMBER 10

The meeting was called to order at 10:25 by Pres. Palm, who announced that all routine reports of Standing and Special Committees had been received by the Governing Board and accepted with thanks to all concerned for their unstinting efforts in the interests of the Society.

1. Dr. Geo. C. Decker presented two reports, that of the Special Committee on Welfare of Entomology, which especially concerned reorganizational changes in the U. S. Dept. of Agriculture, and that on Insect Surveys.
2. D. G. Hall reported on plans for the celebration of 100 years of professional entomology.
3. Dr. H. M. Harris reported for the special committee which studied the time and place of future annual meetings.
4. Dr. A. B. Gurney briefly reported on the activities of the Committee on Common Names of Insects.
5. Dr. P. O. Ritcher reported on his visit to the 1953 Annual Meeting of the Entomological Society of Canada, where he represented the E.S.A.
6. Dr. T. C. Allen presented the report of the Resolutions Committee and moved that it be accepted. Seconded by M. P. Jones. Carried.
7. It was announced that the Committee on Insecticide Terminology has submitted a report, and that it has been requested to proceed in preparing a list of terms for publication.
8. The reports on Publication Policy (Mills Report) and on the JOURNAL OF ECONOMIC ENTOMOLOGY (Upholt Report) were noted. They had been prepared by special committees of the Interim Governing Board.
9. The encouragement given to an Annual Review of Entomology, as a result of a report from a special committee headed by Dr. Edward Steinhaus, was noted.
10. It was explained that authors of papers presented at the 1953 Annual Meeting should notify the Executive Secretary if they plan to publish the papers outside.
11. It was announced that $100 will be contributed to the Zoological Society of London for the support of the Zoological Record.
12. It was announced that $50 will be contributed to the Interim Secretariat of the International Commission of Zoological Nomenclature.
13. The time and place of the 1954 Meeting was announced: The Rice Hotel, Houston, Texas, Dec. 6, 7, 8, & 9, 1954.
14. Dr. E. N. Cory noted the recent death of Prof. P. W. Fattig.
15. H. J. Ryan, Agricultural Commissioner of Los Angeles County, noted the outstanding service of Howard S. Cook of the Citrus Experiment Station in developing publicity aspects of the current meeting.
16. Pres. Palm acknowledged the splendid cooperation of all his Committees, and of all members who assisted him.
17. The new President, Dr. H. H. Ross, was escorted to the rostrum by Dr. E. Gorton Linsley, and Dr. Ross spoke briefly.
18. The names of members of the new Governing Board were read, and those present rose and were recognized.

Adjournment at 11:40 A.M.

ASHLEY B. GURNEY,
Acting Secretary

FINANCIAL REPORT OF THE ENTOMOLOGICAL SOCIETY OF AMERICA

From the Audit Report, by John A. Herl, Certified Public Accountant dated Dec. 2, 1953

Statement of Receipts and Disbursements for the period January 1, 1953 through November 30, 1953

GENERAL FUND, EXHIBIT A

	Total	*Journal*	*Annals*	*Association*
Balance, January 1, 1953				
Funds Contributed by American Assn. of Economic Entomologists	$14,710.94	$ 1,877.79		$ 7,321.01
Funds Contributed by Old Entomological Society of America	512.93		$ 256.46	256.47
Total Funds	$15,223.87	$ 1,877.79	$ 256.46	$ 7,577.48
Receipts				
Subscriptions	$39,759.50	$34,579.30	$5,180.20	
Advertising	1,654.91	1,654.91		
Reprints	2,643.61	2,530.55	113.06	
Back Numbers and Miscellaneous	968.72	951.72		$ 17.00
Journal Paid Papers	250.00	250.00		
Membership Dues	26,263.50			26,263.50
Sale of Indices	968.70			
Interest on Bonds	50.00			50.00
Federal Income Tax—Withheld But Not Yet Paid	180.72			180.72
Undistributed Cash on Hand	5,569.41			
Transfer of Funds From Thomas Say Foundation	5,718.64			
Total Receipts	$84,027.71	$39,966.48	$5,293.26	$26,511.22
Fund Balances After Receipts	$99,251.58	$41,844.27	$5,549.72	$34,088.70
Disbursements				
Printing and Mailing Costs	$38,069.51	$23,933.63	$4,802.75	$
Engravings	808.21	569.65	238.56	
Salaries & Wages-Steno. & Clerical	6,680.49	2,932.22	532.00	2,932.21
Honorarium—Editors	1,200.00	500.00	200.00	
Honorarium—Bus. Mgr. & Interim Secy	1,000.00			1,000.00
History of Ent.—World War II	1,000.00			1,000.00
Postage, Stationery & Office Supplies	3,094.16	1,343.84	148.45	1,343.85
Travel and Meeting Expense	1,810.46			1,810.46
Accounting Service	55.00	27.50		27.50
Telephone and Telegraph	100.24			100.24
Fidelity Bond	37.50	18.75		18.75
Repayment of Loan—Sub. Tr. Co.	14,000.00			14,000.00
Interest on Loan	178.89			178.89
Advertising	31.80			7.50
Miscellaneous Expenses	34.70			34.70
Refunds	226.15	144.90		81.25
Federal Income Tax Withheld 1952—Paid 1953	269.58			269.58
Total Disbursements	$68,596.69	$29,470.49	$5,921.76	$22,804.93
Balance, November 30, 1953	$30,654.89	$12,373.78	$ (372.04)	$11,283.77

Recapitulation

Suburban Trust Co.—Checking Accts.	23,085.48
U. S. Savings Bonds—Series G, 2½%—Cost	2,000.00
Cash on Hand	5,569.41
	$30,654.89

	Indices	*Entoma*	*Cash on Hand*	*Thomas Say Foundation*
Balance, January, 1953				
Funds Contributed by American Assn. of Economic Entomologists	$ 4,884.60	$ 627.54		
Total Funds	4,884.60	627.54		
Receipts				
Sale of Indices	968.70			
Undistributed Cash on Hand			$5,569.41	
Transfer of Funds From Thomas Say Foundation				$ 5,718.64
Total Receipts	$ 968.70	$ —0—	$5,569.41	$ 5,718.64
Fund Balances After Receipts	$ 5,853.30	$ 627.54	$5,569.41	$ 5,718.64
Disbursements				
Printing and Mailing Costs	$ 2,370.45			$ 6,962.68
Salaries & Wages—Steno. & Clerical		284.06		
Honorarium—Editors		500.00		
Postage, Stationery & Office Supplies	4.03	253.39		.60
Advertising		24.30		
Total Disbursements	$ 2,374.48	$ 1,061.75	$ —0—	$ 6,963.28
Balance, November 30, 1953	$ 3,478.82	$ (434.21)	$5,569.41	$(1,244.64)

PERMANENT FUND, EXHIBIT B

Statement of Receipts and Disbursements
For the Period January 1, 1953 Through November 30, 1953

Balance, January 1, 1953		
Funds Contributed by American Association of Economic Entomologists	$19,292.43	
Funds Contributed by old Entomological Society of America	4,758.21	
Total Funds Available		$24,050.64
Receipts		
Interest on Bonds	$ 362.69	
Interest on Savings Deposits	86.53	
Increment in Redemption Value of U. S. Savings Bonds, Series F	123.50	
Life Memberships	50.00	
Total Receipts		622.72
Fund Balance After Receipts		$24,673.36
Disbursements		—0—
Balance, November 30, 1953		24,673.36

RECAPITULATION

Securities

Face Value		*Book Value*	
$ 2,000.00	Province of Ontario, 5% Debenture Bonds of 1959—Cost	$ 2,000.00	
3,050.00	U. S. Treasury 2⅞% Bonds, 1955–60—Cost	3,034.00	
7,000.00	U. S. Savings Bonds, Series G—Cost	7,000.00	
6,500.00	U. S. Savings Bonds, Series F—Current Redemption Value	5,109.00	
18,550.00	Total Securities		$17,143.00

Cash

Cash on Hand	$ 62.50	
Uncashed Bond Coupons	187.69	
Suburban Trust Company—Savings Account (AAEE Acct.)	1,451.78	
First Federal Savings & Loan Association (AAEE Acct.)	1,061.33	
First Federal Savings & Loan Association (ESA Acct.)	4,767.06	
Total Cash		7,530.36
Total Securities and Cash		$24,673.36

SPECIAL JOURNAL FUND, EXHIBIT C

Statement of Receipts and Disbursements
For the Period January 1, 1953 Through November 30, 1953

Balance, January 1, 1953	
Funds Contributed by American Association of Economic Entomologists	$537.60
Receipts	
Interest on Savings Deposit	5.00
	$542.60
Disbursements	—0—
Balance, November 30, 1953	$542.60

RECAPITULATION

Suburban Trust Company—Savings Account	$542.60

THOMAS SAY FOUNDATION, EXHIBIT D

Statement of Receipts and Disbursements
For the Period January 1, 1953 Through November 30, 1953

Balance, January 1, 1953	
Funds Contributed by Old Entomological Society of America	$5,818.64

Receipts		
Sale of Books	$ 741.17	
Interest on Savings Account	15.25	
Total Receipts		756.42
Fund Balance Before Disbursements		$6,575.06
Disbursements		
Transfer of Funds to General Fund	5,718.64	
Excess of General Fund Disbursements Over Receipts	1,244.64	
Total Disbursements		6,963.28
Fund Deficiency, November 30, 1953		$ (388.22)

RECAPITULATION

Cash on Hand	$ 116.90
Suburban Trust Company—Savings Account	739.52
Total Cash	856.42
Less: Due to General Fund	(1,244.64)
Total Deficiency	$ (388.22)

REPORT OF THE MANAGING EDITOR OF THE ANNALS, EXHIBIT E

Statement of Receipts and Disbursements
November 2, 1952 to November 1, 1953

Bank Balance, First National Bank of Pullman, Nov. 6, 1952	$1,002.22
Receipts	
Receipts from Columbus Office	$1,282.05
From Authors for Cuts	569.93
Publication Costs	1,041.61
Royalties	.37
Advertising	155.00
Reprints	8.29
Total Receipts	$3,057.25
Fund Balance After Receipts	$4,059.47
Disbursements	
Office Supplies	$ 36.22
Travel Expenses	294.93
Postage	74.10
Salaries	232.00
Engraving	777.54
Returned to Columbus Office (Checks)	24.60
Spahr and Glenn Publication Costs	2,184.70
Service Charge (Bank)	2.12
Total Disbursements	$3,626.21
Bank Balance, First National Bank of Pullman, Nov. 1, 1953	$ 433.26

COMMITTEE REPORTS

REPORT OF THE RESOLUTIONS COMMITTEE

1. *Be it Resolved:* that the Entomological Society of America commend the Program Committee consisting of Howard Baker, Chairman, L. S. Hitchner, E. G. Linsley, and C. E. Mickel, for arranging a most attractive and instructive program which met the requirements of both economic basic phases of entomology.

2. *Be it Resolved:* that the E.S.A. thank all the participants in this, the first combined meeting of the new Society, which has made possible a broader understanding of the common interests of both applied and academic entomology for the common welfare of all.

3. *Whereas:* Much of the success of our program was due to the high caliber of the invitational papers, therefore

Be it Resolved: that the Executive Secretary, A. B. Gurney, be instructed to write to each of these speakers expressing our appreciation.

4. *Be it Resolved:* that the Entomological Society of America commend the efficient manner in which the following Committee on Local Arrangements has functioned: Roy E. Campbell, Chairman, W. J. F. Francis, R. N. Jefferson, E. H. Littooy,

R. L. Metcalf, H. J. Ryan, A. F. Swain, and C. H. York.

5. *Be it Resolved:* that the E.S.A. extend its thanks to Dr. Charles E. Palm, the first President of the Society, for his able leadership and guidance during the first year of its existence.

6. *Whereas:* E. N. Cory and L. M. Peairs contributed many faithful years of unstinting service to the American Association of Economic Entomologists, and helped pave the way toward the consolidation of the two societies, therefore

Be it Resolved: that the new Entomological Society of America extend to them its thanks and best wishes.

7. *Be it Resolved:* that the E.S.A. request the Executive Secretary to write to the Entomological Society of Canada expressing our appreciation for their letter of good wishes.

8. *Be it Resolved:* that the E.S.A. express its sympathies to the family of Mr. Thomas W. Dent, who prior to his death was President of Spahr and Glenn Co., printers of the Annals of the Entomological Society of America.

9. *Be it Resolved:* that the E.S.A. express its appreciation to Mrs. Walter Ebeling and her Committee who so ably arranged an interesting program of entertainment for the ladies attending the meeting.

10. *Be it Resolved:* that the E.S.A. express its appreciation to the Hotel Biltmore for its facilities and courtesies extended during the period of this meeting.

11. *Be it Resolved:* that the E.S.A. express appreciation to Industry for its part in making the meeting a success.

12. *Be it Resolved:* that the E.S.A. express its appreciation to those responsible for exhibits, registration, and projection. Special mention is also made of the fine publicity given our meeting by Howard S. Cook, Office of Public Information, University of California Citrus Experiment Station, Riverside, Calif.

D. G. DENNING
PAUL O. RITCHER
T. C. ALLEN, *Chairman*

REPORT OF COMMITTEE ON COMMON NAMES OF INSECTS

During 1953 the Committee continued work on proposals for additions to the List of Common Names, and for changes in existing names. In the December 1952 and August 1953 issues of the JOURNAL OF ECONOMIC ENTOMOLOGY lists of changes and additions passed by the Committee were published for approval or rejection by members. From the total of 41 new names and two changes, several have been rejected, as shown in the August 1953 and future publications.

A statement outlining various principles concerning common name activities, prepared in 1952, was published in the February 1953 issue of the JOURNAL.

Two ballots containing a total of 21 proposed additions and two changes were distributed to Committee members in 1953, and results will soon be available so that opinions of the general Society membership may be sought. A moderate number of proposals have been received from members recently, so that another group may be assembled in ballot form for the consideration of the Committee.

This year the main objective has been a preliminary list of common names for the principal families and other outstanding groups. Work on group names was begun some years ago, following instruction from the Association in 1945, and we have taken the notes of previous Committee workers and are attempting to modify or add to them as may be desirable in arriving at a preliminary list of group names.

Tentatively in prospect for 1954 is a new edition of the Common Name List, one which will include an appendix of common names for groups of insects in addition to the usual list of species. The supply of copies of the 1950 list is practically exhausted, and also it is becoming out-of-date.

Respectfully submitted,

DONALD MACCREARY
PAUL O. RITCHER
D. ELMO HARDY
A. E. MICHELBACHER
C. E. SMITH
T. R. ROBB
JOHN B. SCHMITT
HOWARD O. DEAY
ASHLEY B. GURNEY, *Chairman*

REPORT OF THE E.S.A. COMMITTEE ON SURVEYS, DECEMBER, 1953

With each passing year insect surveys of various types have attracted increased attention, until today they are generally regarded as one of the important and perhaps indispensable phases of entomological activity.

During World War II a number of so-called service surveys came into being, and the creation of a national survey designed to assure the early detection of pests that might be introduced into this country through accident or sabotage was proposed. At a special conference on insect surveys held in connection with the annual meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, in December 1951, it was recommended that, insofar as it was practical, all such surveys should be combined into a single cooperative venture, national in scope, with the Bureau of Entomology and Plant Quarantine as the central clearing house and final depository for survey records.

Since timeliness in the use of service survey information is very important, your Committee at its meeting a year ago concurred heartily in the suggestion of Mr. Hoyt, chief of the Bureau of Entomology and Plant Quarantine, that all survey information be channeled through a clearing house in each State, where it could be prepared for immediate timely release locally as it was being summarized for forwarding to the central office in Washington, D. C. In accord with this concept of a truly cooperative State-Federal insect survey, all Bureau personnel were instructed to forward their notes and reports on current insect conditions to the State clearing house. This procedure has strengthened both the State and national insect survey programs.

At the invitation of Mr. Hoyt, your Committee met in Washington, D. C., on May 21–22, 1953, to consider the current status of the whole survey program and make recommendations for further integrating Bureau activities into this program. At this meeting the organization, objectives, and current status of all survey activities underway in the various divisions of the Bureau were reviewed.

As one would expect, the Bureau has many divergent interests in survey work, some of which are only indirectly related to the work of the economic insect detection and reporting service. Some surveys are still in the developmental stage and should properly remain in research divisions, others have to do

largely with quarantine activities, and still others are closely related to large-scale control projects. The Committee therefore recommended that reorganization should proceed slowly and that surveys closely associated with other projects should not be disturbed until it seemed advantageous and proper to do so, but that pertinent information obtained by such surveys should be made available to the detection and reporting section, preferably through the survey project leaders in the various States involved, except where the State leaders were disinterested, inactive, or directed otherwise.

The status of the several specific service surveys that sprang up during the war emergency period was considered at some length, and the Committee finally agreed that it could see little justification for the continuance of such services for the exclusive benefit of limited groups when other equally meritorious causes received no such consideration. It therefore, recommended that these specific service surveys be curtailed as rapidly as possible and that funds available for this purpose be distributed on a more equitable basis. It further recommended that such funds might best be allocated to cooperating States on a matching, or offset, basis. The Committee also pointed out that, since surveys of this type were designed to render a service that would aid farmers in the more efficient use of insecticides and other insect-control measures, the allocations to States might be properly based on a formula that would properly take into account such factors as (1) the value of agricultural production, (2) the duration of the service period (length of growing season), (3) the importance of insect problems, (4) the availability of practical control measures, (5) the demonstrated or probable extent to which farmers could or would use the service, and (6) last but not least, the usefulness of data on migratory species to regions outside of the surveyed area. The Committee further suggested that cooperative agreements with States receiving an allocation of Federal funds contain a provision that individuals employed in this program be required to divide their efforts approximately as follows: important migratory species, such as potato leafhopper, beet leafhopper, corn earworm, armyworm, tobacco budworm, screw-worm, green-bug (50 per cent); other species of interest to several States in the area such as boll weevil and European corn borer (25 per cent); and problems of a strictly local nature (25 per cent).

The Committee also recommended that increased attention should be devoted to the development of surveys designed to detect the possible presence of important insect pests in areas where they have not been known to occur heretofore. It was suggested that the five regional representatives of the Federal Insect Detection and Survey Service might well devote a portion of their time to activities of this type, and encourage state leaders in their respective areas to expand their efforts in this direction. It was pointed out that more nearly adequate surveys of this type would produce data of inestimable value to regulatory officials charged with the responsibility of establishing and enforcing quarantine regulations and to ecologists and biologists interested in the geographical and ecological distribution of species. It was also repeatedly emphasized that such surveys would be most likely to detect the presence of any new insect pests that might have been introduced through accident or sabotage.

In its report presented one year ago the Committee recommended that all members of the Association become identified with some phase of survey work. The response was gratifying but by no means universal, and your Committee therefore wishes to urge again that each member of the Entomological Society of America become an active participant in this cooperative effort.

Respectfully submitted,

H. M. ARMITAGE
W. C. NETTLES
KELVIN DORWARD
R. G. RICHMOND
L. S. HITCHNER
G. C. DECKER, *Chairman*

REPORT OF SPECIAL COMMITTEE ON THE WELFARE OF ENTOMOLOGY AS IT MAY BE AFFECTED BY THE HOOVER COMMISSION

This committee was first appointed by President Boyce on February 4, 1949 and a somewhat detailed report of the committee's activities during the year following the release of the Hoover Commission report presented at the Tampa meeting was published in the JOURNAL OF ECONOMIC ENTOMOLOGY in April, 1950.

In the spring of 1953, the committee was reactivated on a standby basis by President Palm. From time to time members of the committee, the chairman in particular, availed themselves of opportunities to raise questions relative to the reorganization of the U. S. Department of Agriculture with Assistant Secretary Coke, Dr. Shaw, and others. In each instance it appeared that plans for the reorganization of the department did not involve significant changes in the organization of the Bureau of Entomology and Plant Quarantine.

Following the release of Secretary Benson's plan for the reorganization of the Department of Agriculture on October 13, 1953, which did indicate that some radical changes in the organization of the Bureau of Entomology and Plant Quarantine were imminent, the committee arranged to meet in Washington on Sunday, October 25, and the following day the committee presented its views to Assistant Secretary of Agriculture, the Honorable J. Earl Coke. The views of the committee as set forth in this meeting were subsequently transmitted to Mr. Coke in a letter, as follows:

"We appreciate very much the opportunity of talking with you today, and are filing this statement for your further consideration, as was suggested. As we stated, our Committee represents the Entomological Society of America, with over 3,000 members in the United States, Canada and Mexico. We were originally appointed in 1948 when the Hoover Commission Plan for reorganization of the Department of Agriculture was proposed. We sent you on October 12 a copy of the statement which we presented to Secretary Brannan in 1949, as we consider its reasoning still valid. Our committee recommends, for efficiency and economy, that all federal entomological work remain in one unit, as it has operated for nearly a century, except for the period from 1928 to 1934, when the research and regulatory work were separate bureaus. However, if the Administration is unalterably opposed to research and regulatory work in the same organization, we urge that the closest possible coordination be arranged.

"We have been greatly concerned over rumors that several entomological research groups would be split off and assigned to other organizations than the Entomological Research Branch in the Agricultural

Research Service. We are happy to have your definite assurance today that it is planned to transfer only *Forest Insects*. However, we respectfully present to you our unanimous opinion that this transfer of research on forest insects will not contribute to efficiency but may result in duplication of positions and equipment and more expensive operation. As we stated, many forest insects are also pests of orchards, shade trees and ornamentals, and the most practical and scientific approach to their control is through a single entomological research unit which can supply control information to the Forest Service, farmers, orchardists, city and park officials, tree surgeons, commercial sprayers, and others needing these research results. The same research on taxonomy, biology and control will be of value to all these groups. In no detracting sense at all, we may assume that the Forest Service is interested in entomological research chiefly as it may be applied to Forest Service problems, whereas the same research conducted in an over-all entomological unit would have much wider application. It is our opinion, based on observations of other scientific groups that have been scattered, that entomologists working in the Forest Service will find it difficult to maintain the same "esprit de corps" they would have in their own entomological organization. Also, state Extension entomologists, experiment station workers, and the commercial insecticide and pest control industry will find it more difficult to keep close contacts with scattered groups than with a unified organization. We hope you may yet decide to leave forest entomologists in the main entomological branch.

"Although our chief purpose in calling on you was to urge the retention of all entomological research in a single unit, may we again suggest that you give serious consideration to the formation within the Agricultural Research Service of a Division of Plant and Animal Protection which could include all research in entomology, plant pathology, nematology, weed control, defoliants, growth regulators, and any other subjects logically falling into such a group. While we cannot speak for others, we know that many scientists working in the fields just mentioned would welcome inclusion in such an organization which could provide the team approach on so many interrelated problems. It is needless to more than mention the hundreds of cases in which insects and plant diseases are jointly responsible for crop damage and for which joint control measures are used. Creation of such an organization would be especially applauded by the chemical and other industrial groups dealing with these problems, as Mr. Hitchner informed you.

"Thanking you again for the conference today and assuring you of our cooperation, we are . . . "

(Signed by members of the Committee)

In separate personal interviews with Dr. Byron Shaw also held on October 26, Drs. Lyle and Decker were advised that in the reorganization of the Bureau of Entomology and Plant Quarantine activities of a regulatory and large scale insect control nature would be separated from research activities, but that such activities would be retained within the framework of the Agricultural Research Service where the work of the two groups could be effectively coordinated. It was indicated plans for the transfer of forest entomology and forest pathology to the Forest Service had developed to a point where reconsideration seemed improbable at this time. The status of research on insects affecting grain and stored products scheduled for transfer to the Grain Marketing Division seemed a bit uncertain. Both men, however, were assured that aside from the activities just mentioned, the research work of the Bureau of Entomology and Plant Quarantine would be retained in one compact unit to be known as the Entomological Branch which would be grouped with the Field Crops Branch and the Horticultural Crops Branch under a Director of Crops Research, who would be directly responsible to the Director of the Agricultural Research Service.

While your committee regrets its presentations were apparently inadequate to convince the Secretary and his associates that all of the activities of the Bureau of Entomology and Plant Quarantine should be retained in one compact unit, it would appear that the efforts of the committee and the presentations made by many individual members of our Society were reasonably effective and successful. The plan for the reorganization of the Bureau of Entomology and Plant Quarantine as we know it today is far more acceptable than the plan proposed in the original report of the Hoover Commission.

Respectfully submitted,

T. L. AAMODT
BAILEY B. PEPPER
GEORGE C. DECKER
L. S. HITCHNER
CLAY LYLE, *Chairman*

REPORT OF THE COMMITTEE ON INSECTICIDE TERMINOLOGY

Working in cooperation with the Interdepartmental Committee on Pest Control, your Committee has approved for use in the JOURNAL the name "coumachlor" for the rodenticidal chemical 3-(alpha-acetonyl-4-chlorobenzyl)-4-hydroxy coumarin and "dichlone" for the fungicidal chemical 2,3-dichloronaphthaquinone-1,4. "Malathion" has been approved to replace "malathon."

In view of the interest in granulated insecticides the Committee recommends use of the term "granulated" rather than "granular," because the former implies the result of a purposeful process rather than accidental or incidental granularity. Its use follows the precedents of granulated sugar and the granulation of gunpowder. Because of their coarse nature they should not be called granulated *powders*.

The Committee also recommends that the Editor of the JOURNAL be requested not to accept for publication entomological data on chemicals, the composition of which is not fully disclosed. To publish results on a chemical designated only by a symbol or a generic name has little immediate value and practically none from the standpoint of permanent literature. The Committee recommends that authors again be requested to describe clearly and specifically the materials with which they were working, giving their nature and their composition.

In reporting experiments with formulations such as wettable powders and emulsifiable concentrates authors should give the concentration of the active ingredient and in indicating dosages make it clear whether they are in terms of the formulation or of the active ingredient. In certain experiments it may also be desirable to include other ingredients in the formulation. Reports of tests with unknown chemicals, designated only by laboratory number or other code, should not be given space in the JOURNAL.

The Committee feels that there is a need for a readily available published listing of the common

names of insecticides and interim designation of insecticides which have been approved by the Committee for use in the JOURNAL. This listing should include common names and interim designations of pesticides, such as fungicides, which are frequently applied as part of an insecticide spray program. The proposed publication would aid in bringing about the standardization of insecticide terminology in future papers to appear in the JOURNAL. The Committee therefore recommends to the Interim Governing Board the publication of a revised listing of the common names of insecticides in the JOURNAL OF ECONOMIC ENTOMOLOGY and sufficient numbers of reprints for direct distribution to subscribers of the JOURNAL. The Committee further recommends that sufficient numbers of reprints be made available for future reprint requests.

G. S. KIDO
M. C. SWINGLE
C. O. EDDY
C. W. KEARNS
H. L. HALLER, *Chairman*

REPORT OF REPRESENTATIVE TO THE NATIONAL RESEARCH COUNCIL DIVISION OF BIOLOGY AND AGRICULTURE

The annual meeting of the Division of Biology and Agriculture was held April 24, 1953 at the National Academy of Sciences. In attendance were representatives of 26 Scientific Societies, 6 governmental Agricultural Agencies, and officers and guests of the Division.

A motion was passed urging closer affiliation between the Division and the societies associated with it.

Committees were appointed to undertake studies on (a) resources for animals used in research, (b) current trends and needs in biological education, and (c) survey of forestry research in the United States.

Committee reports included (a) plant and crop ecology to determine what is being done in plant science and what needs to be done for the national welfare, and (b) preservation of indigenous strains of maize for future research.

Committees in the Food and Nutrition Board reported on (a) dietary allowances to reflect physiological well being rather than our tendency to get fat as we grow older, (b) nutritionally adequate food supply rather than drugstore prophylaxis, (c) safety of new food ingredients, and (d) low-sodium and optimum fluoride levels for the population.

In this group the Committee on Food Protection has established three basic principles essential for judging the safe use of chemicals in foods under the headings (a) safety in the use of chemical additives in foods, (b) hazards encountered in the use of pesticides on foods, and (c) development of new agricultural pesticides intended for use in connection with food production.

The American Institute of Biological Sciences an association of 53 societies with total membership exceeding 30,000 is concerned with (a) indexing and abstracting services, (b) business services of Journals, (c) job placement of biologists, (d) student needs in biological sciences, and (e) Handbooks of Biological Data.

As member of the Advisory Selection Committee for Zoology 24 applications were reviewed for Fulbright Fellowship Awards for 1954–55. Three applicants were entomologists. Of the 45 applicants in 1952, 9 zoologists and 1 entomologist received awards for the 1953–54 academic year.

As pointed out in previous reports by your Representative the applicant should have an invitation for research or lecturing from the desired institution in a foreign country. Entomologists desiring foreign service should not hesitate to make application but the competition is keen.

FLOYD F. SMITH

REPORT OF REPRESENTATIVE TO AGRICULTURAL RESEARCH INSTITUTE-AGRICULTURAL BOARD

The second annual meeting of this organization was held November 22 to 24, 1953 at the National Academy of Sciences. In attendance were representatives of 42 industrial concerns, 20 scientific societies, 18 governmental agencies, and 36 State Experiment Stations and colleges.

The program consisted of addresses on the (a) relationship of the ARI with the National Research Council and Agricultural activities at home and abroad, (b) research attainments in Agriculture by Industry, U.S.D.A., and Land Grant Colleges, and (c) research activities of the Agricultural Board in the fields of Animal Sciences and of Plant Sciences. Reorganization of the U.S.D.A. and plans for greater efficiency in Agricultural research were discussed in a special address by the Assistant Secretary of Agriculture.

In a report by the Projects and Proposals Committee the 200 suggestions solicited from ARI members were classified under 16 broad categories.

The committee recommendations to the Agricultural Board for further study included:

(a) water in conservation and agriculture
(b) farm machinery and mechanization
(c) broad problem of fats and oils from the agricultural point of view
(d) promotion of more effective cooperation at the research worker level between Industry and Federal and State agencies in all branches of agriculture such as is now in operation in grassland agriculture and the efficient use of fertilizer and lime
(e) metabolic disturbances especially bloat of cattle in relation to certain desirable legumes in pastures, and
(f) plant diseases and pests with emphasis on the international problems, economic aspects, and testing problems and techniques.

The ARI with participation by members of industry and governmental agencies and financial support by industry should encourage the various committees in the Agricultural Board to greater activity on their designated subjects.

FLOYD F. SMITH

CLASSIFIED

Advertisements of commodities for sale or exchange or of services will be entered at 50 cents per issue or $2.50 per year. Advertisements requesting information for use in publications will be charged at the rate of $1 per advertisement to run as long as space permits. Send notices and cash in advance to Ashley B. Gurney, 1530 P St., N.W., Washington 5, D.C., by the 15th of the month preceding publication.

BOOKS FOR SALE: Blatchley—Heteroptera or True Bugs of Eastern North America, 1926, 1,116 pp., 12 plates, 215 figures, 1,253 species treated. Cloth Bound, $10.00.

Blatchley—Orthoptera of Northeastern America. 1920, 784 pp. 7 plates, 246 figures. Paper Binding, $5.00.

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Blatchley Nature Study Club, Noblesville, Indiana

CONSULTANT in ENTOMOLOGY and INSECTICIDES: to manufacturers, custom operators, shippers and warehousemen. Legal service: damage appraisal and litigation from use of pesticides and defoliants or injury to shipping and stored products. Dr. E. R. de Ong, 926 Stannage Ave., Albany, California.

SITUATION WANTED: Entomologist and insecticide chemist, Canadian degrees; now studying for M.Sc.; available 1 June 1954. Eight years research experience; six years experience in charge of control operations in agricultural and medical fields; three years in senior post in tropical agricultural entomology directing research, operations, extension. Physically robust; prefers pest control and/or technical sales work in foreign stations. Fluent Italian and French; three minor languages. Details of experience and references on request. Reply Box D, Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C.

PICTURES AND PHOTOGRAPHIC SERVICES AVAILABLE. Color sound 26 minute movie "Garden Insects." Color silent movie "Fruit Insects" without titles. Wide selection of color slides. 8 x 10 black and white pictures for advertising or editorial use. Insect movies a specialty. Let me know your needs. Lee Jenkins, Entomologist, Polo, Missouri.

POSITION WANTED by medical entomologist, M.S., 36, married, family. Available June 1954. Twelve years experience including public relations, administration, direction of control operations, and research. Publications deal with dengue fever mosquito control, rats and ectoparasites in murine typhus control, and wild rodent ectoparasites with reference to ecology of sylvatic plague. Present government position ($7,168.32 per annum) to be terminated because of budget limitations. Reply to Box Z, Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C.

POSITION WANTED by economic and medical entomologist, M.S., 31, married, one child. Experience includes 3½ years practical economic, research and public health entomology, both laboratory and field research. Desire entomology research, or experiment station work, laboratory and/or field work. Prefer medical entomology work. Available immediately. Reply to Box Y, Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C.

FOR SALE: JOURNAL OF ECONOMIC ENTOMOLOGY, complete set except for Vol. 1. Also numerous entomological bulletins, journals, etc., accumulated during the past 45 years. Write M. A. Yothers, Box 1291, Yakima, Washington.

JOURNALS WANTED: The Entomology Department, Florida Agricultural Experiment Station, needs Volume 34, No. 4, 1941, and Volume 42, Nos. 2, 3, 4, 5, 1949, to complete its set. Will buy these numbers separately or take the two entire volumes. When replying, please give prices. Write A. N. Tissot, Agricultural Experiment Station, University of Florida, Gainesville, Florida.